PRIZE FOR

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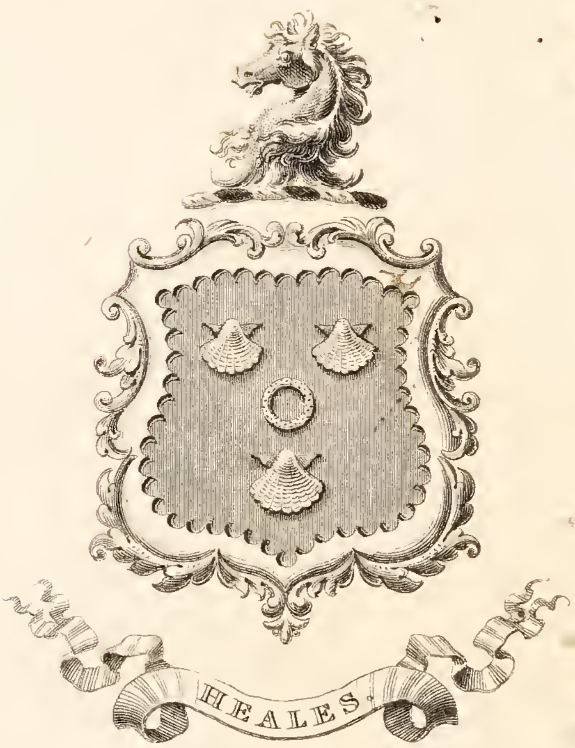
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A

MANUAL

OF

CHEMISTRY:

BY

WILLIAM THOMAS BRANDE,

OF HIS MAJESTY'S MINT;

F. R. S. L. AND E.; PROF. CHEM. R. I., &c. &c. &c.

PART III.

CONTAINING

THE CHEMISTRY OF ORGANIC SUBSTANCES.

INDEX.

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CHAPTER VII.

VEGETABLE PRODUCTS.

HAVING, in the preceding chapters, examined the elementary substances, and such of their combinations as are the result of artificial operations, we are now to turn our attention more exclusively to the *products of organization.* The present chapter embraces the interesting but complicated and difficult subject of *vegetable chemistry*, the objects of which are to inquire into the general phenomena of vegetation, to ascertain the nature of the ultimate elements of vegetable products, to examine the proportions in which they combine, and the general laws that influence them; to ascertain the properties and distinctive chemical characters of the proximate components thence resulting, and to examine into the spontaneous changes to which they are subject, including the phenomena of fermentation.

The *chemical physiology of vegetables* constitutes an important branch of scientific botany, for which I must refer to physiological and botanical authors*, want of space obliging me here to limit myself strictly to the enumeration of a few leading points which bear directly upon chemistry, and which are essentially connected with the theoretical and practical details upon which I must necessarily enter, or which have been touched upon in preceding pages of this volume.

§ I. OF THE GROWTH, STRUCTURE, AND FUNCTIONS OF PLANTS.

SEEDS, from which all plants are originally derived, present infinite variety in form and character; without, however, adverting to the minute history of their different parts, we may here refer to the common *garden bean* as illustrating the general structure of a dicotyledonous seed, and as enabling us to refer generally to their functions and developement. This seed, when the external membranes or coverings are carefully removed, is easily separated into two distinct portions, which constitute the bulk of the seed, and which are termed the *Cotyledons*, they are represented by *a a* in the annexed cut, fig. 235; between them is seen the *embryo* or *germ*, of which one portion *b*, lying between and within the cotyledons, is termed the *plumula*, and the small projecting part *c* is called the *radicle.*

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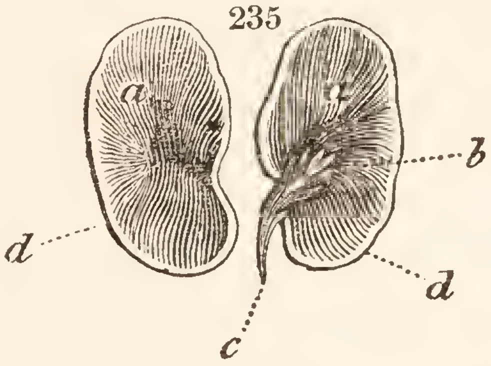

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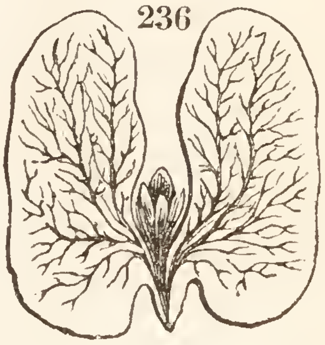

When a seed is placed under favourable circumstances, the different parts begin to grow; the membranes burst, the plumula gradually expands, and rises to the surface of the soil, and the radicle puts forth ramifications, and becomes a root. These changes constitute *germination.* The cotyledons, originally insipid and farinaceous, become sweet and mucilaginous, and furnish materials for the early nutriment of the young plant, before its root and leaves are adequate to their full functions; and vessels are observed for this purpose, as represented in fig. 236. When the root and stem have acquired a certain vigour, the cotyledons either rot away, or become leaves; and the plant then derives its nourishment by the root and leaves, the former collecting materials from the soil, the latter from the atmosphere.

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* Especially to Professor Lindley's "Introduction to Botany."

The circumstances requisite for the healthy germination or growth of a seed are principally the following:—1. A due temperature, which is always above the freezing-point, and below 100°. 2. Moisture in due proportion. 3. A proper access of air, the oxygen of which is slowly converted into carbonic acid. The joint operation of these agents also is required: for seeds exposed to air and moisture, but kept below 32°, will not grow, though they are not injured by the low temperature: nor will a seed vegetate without air, though moisture be present, and a sufficient temperature; this is shown by burying seeds deep in the soil, and by the spontaneous vegetation upon newly-turned earth, in which seeds had existed, but through absence of oxygen had been unable to vegetate. Hence, in all cases of tillage, the seeds should be so sown as that the air may have access; in sandy soils this is easily attained, but in clay, the adhesiveness of the material becomes a source of sterility.

The swelling of the cotyledons is occasioned by the absorption of humidity; accordingly, all seeds enlarge in bulk when immersed in water, but those only of water-plants, will *vegetate* under such circumstances; others require the more free access of air, and grow in the common soil at depths to which the atmosphere easily finds access, and which moisture easily percolates; but in these early stages of vegetable developement the soil is of no further use, for the seed will grow upon wet-paper, cloth, stone, or other materials; in short, air, moisture, and heat, are the only external requisites; everything else depending upon the seed itself. During the expansion and softening of the cotyledons, their albuminous and amylaceous parts become converted into gum and sugar, which are absorbed into the radicle, and contribute to its nourishment and growth into a root. When seeds are made to germinate in confined portions of air, it is found that they do not alter its bulk, but that a part of its oxygen is converted into carbonic acid; hence, one consequence of germination is a diminution in the relative proportion of carbon in the seed, leaving a comparative excess of hydrogen and oxygen, for these are its *ultimate* elements. This evolution of carbon is essential to the growth of the seed, for seeds will not germinate unless free oxygen be present: in hydrogen, nitrogen, and carbonic acid, when aided by moisture, the seed swells at first, but then decays; and in pure oxygen germination is morbidly accelerated; and it is said that certain oxidizing agents, especially the aqueous solution of chlorine, are effective in the restoration of the germinative power to old and dry seeds. All these changes are injuriously affected by *light;* sunshine soon kills the growing seeds, and even diffused day-light operates unpropitiously; we see, therefore, that in a properly-constituted soil, everything concurs in promoting the healthy functions of the seed; air, moisture, and heat, are duly administered, but the direct influence of light is excluded: darkness seems essential to the early developement of all living matter. At first, the *radicle* is most rapid in its growth; the nourishment supplied by the cotyledons going chiefly, if not exclusively, to it; it shoots forth its absorptive fibrils, which now take up nutriment from the soil, and feeding upon this, the plumula rises and puts forth *branches* and *leaves*, the profuse and even infinite variety of which may well excite our wonder and admiration, and is doubtlessly connected with ends and objects of which we at present are ignorant.

The general phænomena of the developement of a seed, are, chemically speaking, the same; but there are extraordinary modifications in the growth of plants derived from those which are *monocotyledonous*, as opposed to those derived from *dicotyledonous* or polycotyledonous seeds: the former class includes the *palm tribe*, and the greater proportion of tropical plants; all gramineous and liliaceous plants likewise belong to it: their growth is *endogenous*, that is, it is the result of additions made internally; the latter class comprehends the ordinary forest-trees, and the greater number of our common vegetables; in them the growth is external, or *exogenous;* and the successive additions to their substance are made upon the exterior of the parts from which they proceed. The *palm-tree* furnishes an instance of endogenous growth: it bears a tuft of leaves at the top of a very lofty cylindrical stem, composed of a dense external layer of wood, and increasing in porosity towards the centre; its general texture appears similar throughout, and the distinctions of pith, wood, and bark, are not perceptible in its transverse section: its mode of growth is peculiar; it first forms a circle of leaves, which after having attained a certain size, are succeeded by another circle growing from the interior of the former: these are reproduced annually, each crop exerting an outward pressure upon the ligneous formation of the preceding year, which at length becomes too dense to admit of further distension: the growth of the inner layers is then necessarily directed upwards, so that they each successively rise by distinct stages, always proceeding from the interior; but the stem never increasing in diameter after the consolidation of its exterior layer. A disc of leaves shoots yearly from the new layer of wood, and when these fall off they leave a circular mark upon the stem, so that the age of the tree may be judged of by the number of these alternations of circular knots. Similar appearances may be observed upon grasses.

The section of a bicotyledonous tree, or one of exogenous growth, exhibits several distinct formations: there is a central *pith*, the structure of which is cellular or spongy, and not tubular, and which is liable to much variation in quantity and character in different plants or trees, and at different stages of their growth: it is surrounded by concentric layers of *wood*, the exterior portions of which are softer than the interior; hence the distinction into *alburnum* or *new wood*, and *duramen* or *heartwood*, the former being paler than the latter, which is often brown, and in ebony, black. The wood is enveloped by the *bark*, which consists also of concentric layers, of which the innermost bears the name of *liber;* the whole is covered by *cellular tissue* and *epidermis:* the bark, like the wood, when more than one year old, is composed of as many layers of cellular integument and woody fibre as it is years old, the former being external, and the latter internal, in each layer, and every layer being formed beneath the previous one, and therefore next the wood: so that the bark is to a certain extent elastic or distensible; but after a time it splits, as in the *elm*, the *cork*, and the generality of European trees; or it peels off, as in the *plane* and *birch.* In the spring of the year a viscid substance is found between the bark and the wood, which is termed *cambium.* Besides these distinct formations which trees of exogenous growth present, the horizontal section of the stem exhibits a number of rays or lines proceeding from the pith to the circumference; they are apparently composed of one or more layers of cellular tissue, and are termed *medullary rays;* in longitudinal section they give to many woods a peculiar satiny lustre. As a new layer of wood and bark are formed annually, it is customary to judge of the age of trees by the number of concentric rings which either of them exhibits; but these calculations are open to many fallacies. (See Lindley's *Introd. to Botany*, book i., chap. ii.)

The *cuticle*, or most superficial membrane of plants, is extremely varied in different vegetables, and in different parts of the same plant: it extends over every part of the plant; it allows, by its pores, or *stomata*, of absorption and transpiration, and being generally transparent, at least upon the leaves and flowers, it admits the influence of light. The cuticle varies in texture and appearance in different plants. On the currant and elder tree, it is smooth, and scales off: on the fruit of the peach, and on the leaf of the mullein, it is covered with wool; on the leaf of the white willow, it is silky; in several plants, it is covered with hair and bristles, which in the nettle are perforated, and contain a venomous fluid: on the plum and upon many leaves, it is varnished with a resinous exudation, which prevents injury from rain: it is fungous on the bark of the cork-tree; and on grasses, on the equisetum, and especially on different species of the rattan, it is covered with a glassy network of silica. This fact first occurred to Sir H. Davy in 1798, and led to experiments by which he ascertained that siliceous earth existed generally in the epidermis of the hollow plants. "It serves," he observes, "as a support, protects the bark from the action of insects, and seems to perform a part in the economy of those feeble vegetable tribes, similar to that performed in the animal kingdom by the shell of the crustaceous insects." Silica is also found in the hollow stem of the bamboo, constituting the substance called *tabasheer.* It is to the large quantity of silica existing in grasses, that the glassy character of the products of burned hay and corn stacks is to be attributed.

Under the cuticle, or epidermis, is the *parenchyma;* a soft substance, appearing under the microscope of a honeycombed or hexagonal cellular structure, resulting from the mechanical laws which influence the pressure of soft cylinders.

As the tree grows, the stem and the root both send out their branches or ramifications, and the phenomena of their production are extremely curious and interesting: the branches, and their subdivisions, are generally produced with remarkable regularity, so as to give a defined outline to the shrub or tree, except where unequal exposure to air, light, or heat, causes one side to expand more luxuriantly than the other: the root, too, in an uniform soil, extends equally on all sides, but various causes likewise interfere with its growth, and it sometimes presents very extraordinary diversions from its usual progress.

I have already noticed the infinitely-varied forms and textures of the *leaves* of plants; their anatomy has been closely investigated by botanists as well as the mode of their growth or formation; they for the most part exhibit a beautiful skeleton or frame-work of ligneous fibre, supporting a delicate vascular and cellular structure, and are covered by cuticle. The *flowers*, and their parts, are analogous in anatomical structure.

Besides the *cells*, which have been mentioned as constituting a large proportion of the vegetable texture, there also are membranous *tubes* interspersed through their various parts, which exhibit extraordinary varieties in their form, characters, and dimensions; some are simple, others jointed, or spiral, or annular, or perforated; their contents also, as well as those of the cells, are very various; they contain crude or concocted sap, various secretions, or products of vegetation, and air.

The *nourishment of plants* is partly derived from the soil, through the medium of the roots, and partly from the air, by means of the leaves. In spring, before the leaves appear, the roots are chiefly active, and absorb soluble matters from the soil, derived from the decay of the fallen leaves of the preceding autumn. The absorptive power of the root is not merely capillary, but peculiar and vital, and seems to reside in the terminal fibres or *spongioles*, and not in the radicular branches generally; hence the injury which is generally inflicted upon the root by removal or transplantation; the necessity of carrying with the root a sufficient ball of earth to prevent the abrasion or fracture of the spongioles; and the advantage of growing plants in pots, which are intended afterwards to be removed into the border. The roots absorb some substances more readily than others, but they have no selective power in respect to the most appropriate nutriment; and Saussure has shown that they, in many instances, absorb poisonous substances more rapidly than others. Marcet's experiments have taught us that white arsenic and corrosive sublimate are poisonous to vegetables as well as to animals; and that vegetable poisons are equally active, such as opium and prussic acid, which when applied, even in very dilute solution, to the roots, cause the plant to droop and die. It has been supposed that the access of air to the roots of plants is not only not prejudical, but that it favours the healthy performance of their functions.

The fluids which are absorbed by the roots of plants, constitute the *crude or ascending sap**; they are circulated in appropriate vessels throughout the vegetable fabric, being transmitted more copiously to some organs than to others, and contribute to the formation of new parts, and to the composition of their various secretions. Hales, long ago, demonstrated the power with which the sap ascends in its vessels, and endeavoured to account for the rapidity and the direction of its progress; but this phenomenon is still unexplained: a valvular system in the vessels, somewhat similar to that of the veins of animals, was presumed to be efficient in preventing the retrograde motion of the sap; but the well-known fact, that a plant may be inverted, and that the branches may be made roots and the roots branches, subverts such an hypothesis. When the sap has once entered its vessels it seems invariably to tend (perhaps in the direction of least resistance,) towards the *leaves*, which as regards its chemical changes and elaboration, are certainly most important and essential organs. The quantity of the sap which, in many plants, is thus carried upwards from the roots, is very surprising, considering the source whence it must be derived; it may often be abundantly collected by cutting off a branch of a young and thriving tree or shrub, and it is then seen to ooze from the section, flowing over in drops, and running down the stem. The vast evaporation, also, that takes place by the leaves, must be chiefly, if not exclusively, supplied by the roots. Many plants, examined by Woodward, lost, in three months, one hundred times their own weight of water by transpiration. Hales found a sun-flower lose one pound four ounces, and a cabbage one pound three ounces in twenty-four hours, by this process. This perspiration is said to depend upon the number of the *stomata*, and therefore to be less in evergreens, in which they are few, than in deciduous and herbaceous plants. Whenever the balance between the absorptive power of the spongioles and the emissive power of the leaves is disturbed, the plant suffers, as we see by the drooping of the leaves in a warm and dry atmosphere on the one hand, and in a dry soil on the other.

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* The sap of plants is of very various composition, and contains, besides certain proximate vegetable principles, several saline substances, especially the acetates of potassa and of lime: it also often exhibits traces of uncombined vegetable acids. The sap of the elm, beech, hornbeam, and birch, have been examined by Vauquelin (*Ann. de Chim.*, xxxi.): he found extractive and mucilaginous matter, and acetic acid combined with potassa and lime. The solid matter afforded by their evaporation, yielded an ammoniacal smell, probably owing to albumen: the sap of the birch afforded saccharine matter. Dr. Prout has given some account of the sap of the vine. Its taste is sweetish, and its specific gravity scarcely exceeded that of water. Potassa and ammonia reddened it, and precipi-

The leaves are the seat of the most important vegetable functions; they are organs of absorption and emission, of nutrition and of digestion. The sap which in its crude state, as it rises from the roots, is extremely dilute, and consists of little else than water, with gum and sugar, and traces of saline matter, is concentrated by evaporation in the leaves, and receives an addition of carbon from the carbonic acid in the atmosphere; air, and light, and heat, are active in these changes, and the leaves are

tated red flocks soluble in acetic acid. It was rendered slightly turbid by nitrate of silver, subacetate of lead, ferrocyanuret of potassium, and oxalate of ammonia. It contained carbonic and acetic acids, and an alkali. (*Ann. of Phil.*, v.) Professor Scherer analyzed the sap of the common maple: it had a milky appearance, and sweet taste. It did not affect litmus or turmeric. It was precipitated by oxalate of potassa, nitrate of silver, and baryta-water. When evaporated, it yielded a salt, with base of lime, containing a peculiar acid, which he calls *aceric acid.* (Schweigger's *Journal*, iv.)

The sap of the rose-tree has been examined by Mr. Addams. (*Quarterly Journal*, iv., 147, *N. S*) In twelve fluid ounces he found

Oxalate of lime . . .	2.900
Acetate of lime . . .	1.097
Acetate of potassa . .	0.700
Gum and extractive .	2.100
Sugar, &c. (soluble in alcohol)	0.100
Loss	0.353
	7.250

It is, however, almost impossible to collect the ascending sap without admixture of some other juices of the plant, so that the analyses only afford approximations to its real composition.

admirably adapted to such complicated purposes. Their influence in modifying the composition of the sap, and in supplying food to all parts about them, is shown by the mischief which ensues when they are removed; and we have evidence of their emissive or perspiratory powers in the watery vapour which they give off, and which sometimes collects in drops; they also occasionally secrete grosser compounds, such as honey-dew, wax, and ladanum. If we place a healthy leaf between two cold plates of glass, we generally observe that the greatest visible transpiration is from the lower surface, and the organization of the leaf is apparently such as to render that surface the most apt for the escape of watery vapour: but in some plants the upper surfaces of the leaves are said to be most active, so that probably both the absorptive and excretive power of the leaves varies in different individuals.

One of the most curious and important functions of the leaves is their power of decomposing the carbonic acid which is always present in the air, retaining its carbon, or a portion of it, and emitting pure oxygen (p. 65); and to show how important an agent light is in inducing these chemical changes, it is found that they only go on under its influence (p. 183,) and that in the dark they are either inactive, or even deteriorate the air (as we are in the habit of saying,) by the addition of carbonic acid; upon the whole, however, although different plants act very differently in this respect, there can be no doubt that the influence of the vegetable creation upon the atmosphere is purificative; that is, that part of the carbonic acid produced by animal respiration, and by combustion and other causes, is decomposed by the leaves, and that they evolve more oxygen during the day-time than carbonic acid during the night. This is well illustrated by Dr. Priestley's experiments on the sprigs of mint already cited (p. 65.) We now, also, shall duly appreciate the importance of aqueous vapour, and of carbonic acid, as components of the atmosphere (p. 411), for that the leaves often absorb moisture from the air is shown by the reviving influence of damp air upon a drooping plant, or of the direct application of water to its leaves. It has also been proved that no oxygen is evolved by plants, except carbonic acid be present in the air. Aquatic plants furnish a striking corroboration of these observations; they decompose the carbonic acid of the air in water, and evolve oxygen during the influence of light; this carbonic acid may be furnished from various sources, but part of it is often derived from the respiration of fishes, and would accumulate to a noxious extent were it not replaced by the oxygen emitted by the plants; hence it is that fish never thrive in waters which are exempt from vegetation; and that in ornamental vases and basins, in which there are fish, aquatic plants are at the same time desirable. But, although plants will not thrive without access to carbonic acid, its excess is prejudicial, and it has been found to operate as a poison when it exceeds one-twelfth of the atmospheric air; in such proportion, however, it never exists in the free atmosphere.

Saussure's experiments upon the functions of the leaves have taught us the curious fact, that along with the carbon, a portion of oxygen is also absorbed, and this (in the absence of light) from an atmosphere not containing carbonic acid. Fresh leaves, exposed *in the dark* under a bell-glass of air, absorb one portion of oxygen, and convert another into carbonic acid: if afterwards *exposed to the light*, and especially to the direct rays of the sun, they re-absorb the carbon, and give out the whole of the oxygen, gradually restoring the air to its pristine condition. Very succulent leaves (those of the *Cactus opuntia* for instance), absorb oxygen in the dark, and again evolve it in the light: in the course of 30 hours they thus absorbed more than their own bulk, and it could not be extracted from them either by warmth, or by exposing them in the vacuum of the air-pump, though in the sun's rays they invariably emitted it. These properties belong to the leaves of all plants, but the effects vary much in degree in different genera; they are also probably more or less resident in all the *green parts* of vegetables, but are not possessed by the bark or roots.

The changes which the sap undergoes in the leaves are extremely complicated; it is not merely concentrated by evaporation, but is rendered the source of the wonderful products which characterize the different genera of plants, and of the materials required for their growth: these changes are sometimes manifest in their obvious properties; thus, the leaves of some species of *Bryophyllum*, are said to be sour in the morning, tasteless at noon, and bitter at night, reddening litmus at one time of the day and not at another; the flowers of the *Cichorium intibus* are white or blue, according to the intensity of the day-light; and many fruits are observed to be more acid in the morning than in the evening.

The circulation of the sap, as has been before remarked, is involved, as to its cause, in great obscurity, and even the general direction of its progress in the growing vegetable has not been very satisfactorily ascertained; but the researches of Andrew Knight (*Phil. Trans.*, 1801), and other experimental physiologists, render it probable, that the chief ascent of the sap from the roots to the leaves, is in the vascular system of the *alburnum* and outer layers of wood, that it is thence transferred into the leaves, and that having there undergone changes, some of which have been adverted to, it descends chiefly, but not exclusively, by the *liber* or inner layer of bark, giving rise to the secretion of *cambium*, to the formation of new wood, and to the deposition or separation of gum, resin, and other characteristic proximate principles. The proofs of this circulation of the sap are, that if a branch be cut through in the spring, sap will exude more or less from its whole surface, but most copiously from the *alburnum;* if it be cut half through, and a semicylindrical piece removed, the principal exudation of sap upon the upper half will then be in the inner layers of the bark, and the liquid which there oozes will be different from, and more concentrated than that which runs from the outer layers of the wood; as if the *ascending sap-vessels* had been divided in the alburnum, and the descending in the liber; and if a ring of bark be carefully removed from a branch of a young tree early in the spring, the portion above the section will be turgid, and perhaps bear blossom and fruit, indicating symptoms of accumulation of sap, the escape of which from the cut surface is soon prevented by the induration of the inspissated descending sap, and ultimately by the growth of new ligneous matter, the proportion of which is enormous upon the *upper*, as compared with that upon the under line of section. This explains the influence of *ringing* the branches of fruit trees, with a view of rendering them productive; and the difference between the ringed and the other branches is often very striking, late in the season, as affecting the fruit, leaves, and general aspect of the plethoric parts.

Plants are in general extremely susceptible of impurities in the air that surrounds them; slight modifications, therefore, in the composition of the atmosphere, are more or less prejudicial to their growth; especially when not under the influence of light: thus, although in the sun, a plant will thrive in air containing 8 or 10 *per cent.* of carbonic acid, such excess of that gas is fatal to it in the shade. The experiments of Drs. Christison and Turner upon this subject (Brewster's *Journal*, 1828, and Lindley's *Introduction*, book ii., ch. v.), are very instructive; and instead of being surprised at the injury which plants sustain in the atmosphere of London, lead us to wonder that they are not more generally affected by it; there is no doubt, however, that plants, like animals, vary in regard to the delicacy of their constitutions, and that some are infinitely more susceptible, not only of changes in the temperature and humidity of the air, than others, but are fatally influenced by the presence of foreign matters which more hardy tribes resist. Dr. Macculloch has given us some curious facts upon this subject, very interesting to the metropolitan and suburban horticulturist, in a paper on culture of *Mural Plants*, in the *Quarterly Journal of Science* for 1829.

The influence of the *flowers* of plants upon the atmosphere, is probably as various as are their infinitely-varied forms, colours, odours, and composition; even in the light, they invariably deteriorate the air; that is, they convert a portion of its oxygen into carbonic acid, and that, more rapidly than the leaves are found to do, in the dark: the sexual organs of the flower have been shown by Saussure materially to influence the destruction of oxygen. From M. Berard's experiments on the action of *fruits* upon air (*Ann. de Chim. et Phys.*, xvi.), it appears that they, in all cases, tend to the production of carbonic acid, and that this loss of carbon is essential to the ripening of the fruit; for when deprived of oxygen, the fruit dies. When fruits rot, they first change a portion of the surrounding oxygen into carbonic acid, and then liberate the same gas ready formed. He considers gum and lignin as the principles in unripe fruits which chiefly tend to the formation of sugar during their ripening, and has given several analyses of fruits in illustration of these views, a few of which are selected in the following Table: the elements of water are also probably concerned in the change.

	CHERRIES.		PLUMS.		PEACHES.		PEARS.		APRICOTS.		
	Green.	Ripe.	Green.	Ripe.	Green.	Ripe.	Green.	Ripe.	Green.	Riper.	Ripe.
Vegetable albumen	0.21	0.57	0.45	0.28	0.41	0.93	0.08	0.21	0.76	0.34	0.17
Colouring matter	0.05	..	0.03	0.08	0.27	..	0.08	0.01	0.04	0.03	0.10
Lignin	2.44	1.12	1.26	1.11	3.01	1.21	3.80	2.19	3.61	2.53	1.86
Gum	6.01	3.23	5.53	2.06	4.22	4.85	3.17	2.07	4.10	4.47	5.12
Sugar	1.12	18.12	17.71	24.81	0.63	11.61	6.45	11.52	Trace	6.64	16.48
Malic acid	1.75	2.01	0.45	0.56	1.07	1.10	0 11	0.08	2.70	2.30	1.80
Lime	0.14	0.10	Traces	Traces	0.08	0.06	0.03	0.04	Trace	Trace	Trace
Water	88.28	74.85	74.57	71.10	90.31	80.24	86.28	83.88	89.39	84.49	74.87

The evolution of *heat* during the germination of seeds, is well shown by the rise of temperature in the process of malting; and the temperature of the organs of the flower, during the period of their activity, is, in some plants, many degrees above that of the atmosphere: these cases of the production of heat, must not be confounded with those of fermentation; they are perfectly distinct, especially in the latter case. It appears probable that all plants have a power, dependent upon their vitality, of maintaining, to a certain extent, an equable temperature; but how far their internal heat can be affected by external causes, has not as yet been satisfactorily ascertained.

I have now briefly enumerated a few of those phenomena of vegetation in which chemical changes are principally concerned; the whole inquiry is full of interest to the chemical physiologist. Among the *vital powers* of plants, there are some which I have not adverted to, because apparently unconnected with the subject before us; such as the *sleep* of plants; the expansion and contraction of their flowers and leaves, dependent upon the presence or absence of light; their spontaneous and their involuntary motions, as in the *Hedysarum gyrans*, the *Mimosa pudica*, the *Dionæa muscipula*, and the influence of electricity upon the latter.

It has been stated that carbon, oxygen, and hydrogen, and frequently nitrogen, appear to be the essential ultimate elements of vegetable products, and it is evident that they derive a part of their carbon and oxygen from the air: the source of their hydrogen and nitrogen is less obvious; they may possibly decompose water; may derive nitrogen from the air, or both from the soil. That plants derive much of their nutriment from the latter, is obvious from its impoverishment, and from the direct influence of nourishment so applied; the substances thus taken up, are, or at least may be, very complicated, consisting of a variety of soluble matters, of inorganic as well as of organic origin; and the rapidity or facility with which they are imbibed depend upon a variety of obscure causes, and partly upon the relative magnitude and absorbent powers of the leaves; for it is, I believe, admitted, that plants with large systems of leaves, absorb less from the soil than those which are less liberally provided with foliage; and, independent of this, some plants are certainly more voracious and gross feeders than others, thriving in proportion to the richness of the soil, and acquiring odour and flavour from the manure with which they are supplied.

Manures are of *vegetable*, *animal*, or *mineral* origin. The two former are capable of affording two of the essential ingredients of plants, namely, carbon and hydrogen; they may also yield some of the immediate principles of vegetables. The mere existence, however, of vegetable matter in the soil, is not sufficient to constitute it a *manure;* it must be reduced to a soluble state; to a state in which it can be absorbed by the roots of a growing vegetable; this is often effected by fermentation or putrefaction, or by applying the vegetable matter in a green state, as by ploughing in a green crop. Where the vegetable matter is in an inert insoluble form, it will be of no avail unless rendered active and soluble, which is effected either by mixing it with such kinds of animal matter as undergo quick putrefaction, such, for instance, as dung, rotten fish, or decaying parts of animals; or, by the operation of alkaline bodies, such as quicklime, &c.

When newly-burned lime is strewed over a soil containing inert vegetable matter, it acts upon it, and renders it more or less soluble; while the lime, by absorbing moisture and carbonic acid, is slaked, and passes into the state of chalk, which is often a useful addition to the soil: but when limestone contains magnesia, it remains caustic, and sometimes proves injurious.

The limits of this volume prevent my enlarging upon these topics, which are full of interest, and demand a separate work for their illustration. Such a work Sir H. Davy published several years ago, but the general progress of the science, since that time, has been such as materially to affect all its collateral branches; and the views and doctrines that were then plausible, now require revision and modification.

Having now noticed a few of the leading facts connected with the structure and growth of plants, which bear upon their chemical physiology, I shall proceed to the methods of analysis applicable to the discovery of their ultimate elements, and to the proportions in which they are combined in their proximate or immediate principles.

§ II. Of the Composition and Analysis of Vegetable Substances, and of their ultimate Principles.

Although the *ultimate principles* of vegetable substances are few in number, yet by being combined in various proportions, they give rise to a series of compounds materially differing from each other, and which are called their *proximate components.* It has just been stated that *carbon*, *hydrogen*, and *oxygen*, are the principal ultimate components of vegetables, and that some afford *nitrogen;* in some there are traces of sulphur; and in their sap or juices we find small proportions of potassa and of lime, and sometimes of soda and of magnesia: these bodies are combined with acids, and are chiefly obtained by burning or incineration. It has already been said, that some plants contain silica; sulphate of lime is found in clover; nitrate of potassa in the sap of the sun-flower; and nitrate of soda in barley. Common salt, and some other chlorides, are frequent ingredients in marine plants; phosphate of lime is found in oats and some other seeds; and nearly all vegetables yield traces of oxide of iron, and many of oxide of manganese. In Saussure's *Chemical Researches on Vegetation*, and in Thomson's *System of Chemistry*, are copious tables, showing the earthy and saline constituents of vegetables.

But the elements with which we shall almost exclusively have to deal, in our examination of vegetable products, are the four first, and the number, and the varied characters of the compounds to which they give rise under the influence of organization, is certainly most extraordinary: of this diversity, some of the causes will become apparent as we proceed; others have not only repulsed all attempts at explanation, but even baffle our most unlimited conjectures.

There is another leading distinction between *organic* and *inorganic* compounds, which is, that in the *latter* the elements are generally united in *binary* arrangements; thus, *crystallized sulphate of soda* is composed of sulphuric acid, soda, and water, which are *binary* compounds of sulphur and oxygen, sodium and oxygen, and hydrogen and oxygen: &c.: but *organic* products are *ternary* or *quaternary* combinations, which we can scarcely ever imitate by artificial processes; and in the formation of which a greater number of simple atoms are usually concerned: sulphuric acid, for instance, is a compound of 1 atom of sulphur and 3 of oxygen; but *tartaric acid* consists of 4 atoms of carbon, 2 of hydrogen, and 5 of oxygen; hence, in organic compounds, the proximate atoms are heavier, or the equivalents larger, and the saturating powers less, than in inorganic combinations: there are, however, some instances of binary organic compounds; caoutchouc, and some oils, are composed only of carbon and hydrogen; but then there is this distinction; that they do not consist of one atom of the one element united to one or more of the other, but several atoms of each element are combined; and in most cases, no simple relation between them can be observed.

No peculiarity of organic combination is more remarkable than the extreme *difference* between substances constituted of *similar* elements; sugar, gum, &c., consist of carbon, hydrogen, and oxygen; but those substances have neither the characters of acids or bases; acetic, succinic, citric, and formic *acids* also consist of the same elements, but in different proportions or differently congregated. Oxalic acid presents a striking peculiarity; it is composed of carbon and oxygen only, and contains less oxygen than carbonic acid, and yet is one of the most powerful acids; it is either a direct product of organization, or obtained indirectly from other organized compounds.

If, therefore, we endeavour to combine the elements of organic bodies by *artificial* operations, they show a tendency to pass into binary, and not into ternary or quaternary compounds; and even in the living body, products that have already been organized, appear essential to the formation of new ones; thus, vegetable life is in great measure supported by the decay of former vegetables; and graminivorous and carnivorous animals require vegetable and animal substances for their sustenance; for although it be true that carbon, hydrogen, oxygen, and nitrogen, are the ultimate elements of our food, we should soon starve upon charcoal, and water, and nitrogen, or upon any of their compounds *which had not already gone through the process of organization.*

As, therefore, we cannot so combine the insulated inorganic elements as to imitate the products of organization, we are deprived, in our researches upon these forms of matter, of the aid of *synthetic* proof, in the ordinary acceptation, at least, of that term; and in determining the nature and the relative proportions of the elements of organic compounds, we are limited to *analytic* operations; and even in them (as we shall presently find) numerous difficulties occur, especially affecting the determination of the integral atomic weights of the compounds, and the theory of their elementary arrangements.

The first attempts at the analysis of vegetable substances, consisted in subjecting them to *destructive distillation*, and this method was greatly extended and improved by Hales, Priestley, and the earlier pneumatic chemists, who paid especial attention to the gaseous products of such operations, which, together with aqueous and oily liquids, and a residue of carbon, constitute the results of the process; hence the conclusion of the older chemists, that air, oil, water, and *earth*, including under that name, the carbonaceous residue (or *caput mortuum*, as they called it,) were the universal *elements* of organic bodies. It is, however, evident that most of these are secondary results, that they are *products* of the operation; and accordingly their composition and relative proportions are liable to infinite variation, dependent upon the manner in which the distillation has been effected. In modern analysis, therefore, this method is rejected; or at least only adopted where some specific product is to be examined, or where some general inference is to be drawn from the nature or proportions of the newly-produced compounds: *ammonia*, for instance, denotes the presence of nitrogen; a large quantity of *oil* announces excess of hydrogen; and of *acid* excess of *oxygen;* the uncondensed *gases*, and the residuary *carbon* may also be examined.

The following is the form of apparatus in which these operations may be carried on:

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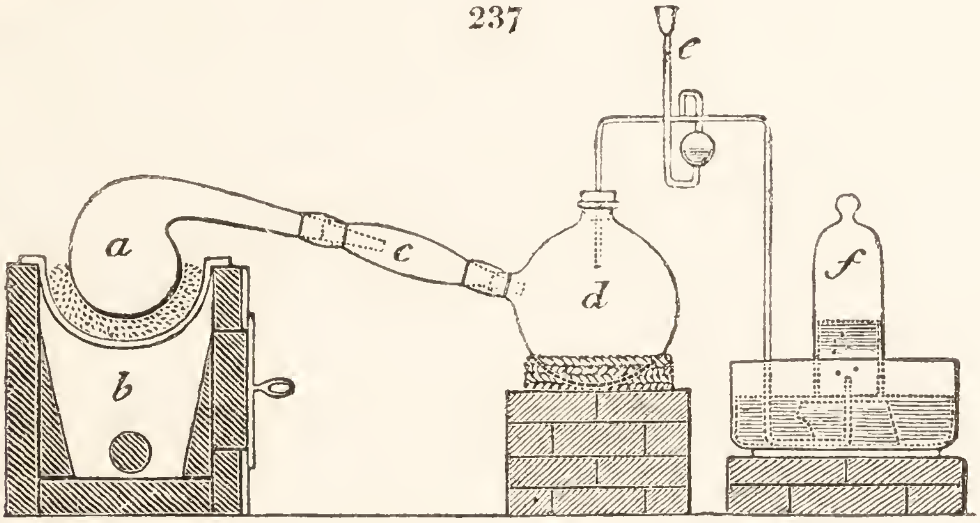

a is a luted glass or earthern retort, containing the substance to be decomposed, and placed in a sand-heat *b*, which is gradually raised to a red-heat. It is connected by the adapter *c* with the receiver *d*, which is kept cool for the condensation of the liquid products; the gases pass into the bell-glass *f* standing over water or mercury. *e* is a *tube of safety*, to allow for sudden expansion or contraction; there being in its lower part a small quantity of mercury which is occasionally elevated or depressed. The joints are secured by strips of bladder.

If we again refer to the nature of the *ultimate elements* of organic bodies, it is obvious that combustion in oxygen will enable us to determine their relative proportions. To take the simplest instance, let us suppose the subject of analysis to consist of *carbon* and *hydrogen* only; in that case the products of its entire and perfect combustion in excess of oxygen would be *carbonic acid* and *water:* the quantity of *carbonic acid* being determined, that of the *carbon* which had formed it, might be inferred; and this ascertained, and compared with the *original weight* of the substance, would give the proportion of *hydrogen*: thus, supposing 7 grains of the substance under examination yielded, by combustion in oxygen, 22 grains of carbonic acid, it would have consisted of 6 carbon + 1 hydrogen; for 22 carbonic acid (consisting of 6 carbon + 16 oxygen), are equivalent to 6 carbon. If the subject of analysis were a compound of carbon, hydrogen, and oxygen, it might be expedient to determine the weight of the produced *water*, with a view of arriving at that of the hydrogen. Let us suppose 15 grains of a compound of carbon, hydrogen, and oxygen, to afford 22 grains of carbonic acid, and 9 of water; then we should again have 6 of carbon, and 1 of hydrogen, (for 9 water = 1 hydrogen and 8 oxygen) and there would be a deficiency of 8 grains, (required to make up the original 15) which would be the inferred weight of the oxygen. When *nitrogen* is present, its quantitative determination requires precautions to which I shall presently advert. So far, therefore, the mere *theory* of these ultimate analyses by combustion, is sufficiently simple, but the difficulties of *manipulation* are numerous and considerable; they relate, first, to the mode of effecting the *entire* combustion of the organic compound, and secondly, to the accurate collection and quantitative determination of the *products* of combustion*.

Gay Lussac and Thenard (*Recherches Physico-Chimiques*, tom. ii.) were the first who endeavoured to meet these difficulties, and to furnish accurate analyses, upon the principles just stated. The method of effecting the combustion of an organic product in oxygen, which they originally adopted, consisted in forming a given weight of it into one or more pellets, with a requisite proportion of *chlorate of potassa*, and then subjecting it to a red-heat. An account of their process is given in Thenard's *Traité de Chimie*, with the following arrangement and description of the apparatus. A hole is made through a brick, L, and the glass tube A A′ is passed through it as far as to the small lateral tube BB′, which passes into the mercurial trough. The lower extremity of the tube rests upon the grate G, where it is to be heated red-hot by charcoal inflamed by the lamp H. A brass cock is fitted, by grinding, to the tube, CC′. It has a solid plug, DD′, in which is a cavity large enough to contain one of the balls to be analyzed, and which is introduced at the opening E. The plug is then turned round, and the ball falls into the red-hot part of the tube, where it burns, the gases passing into the mercurial apparatus. F F′ is a basin, into which ice may be introduced to keep the metallic parts of the apparatus cool. It is convenient to case the lower part of the tube A in iron, as it is sometimes blown out at that part by the expansion within.

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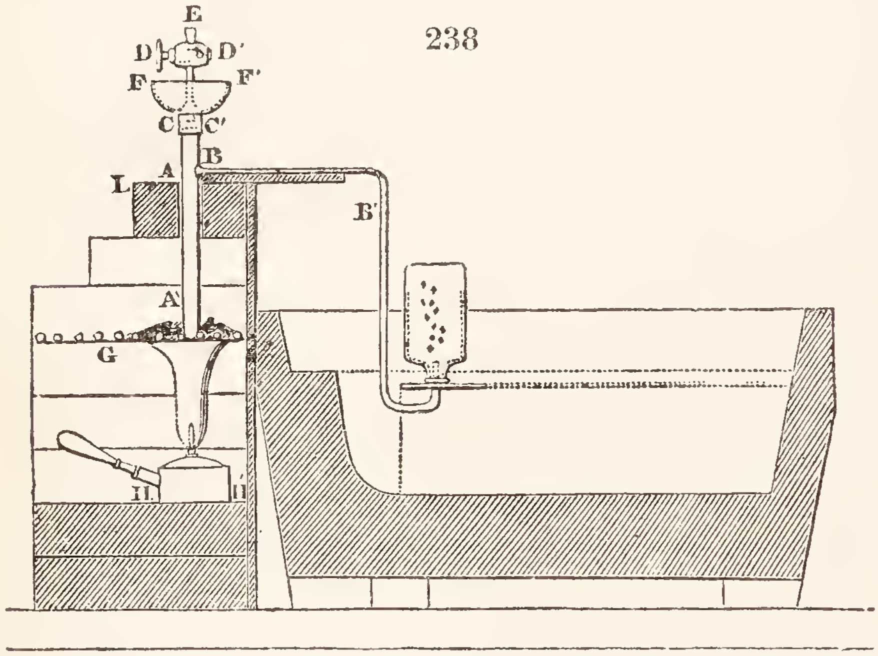

I shall not advert to the further proceedings with this apparatus, because it is rarely used. The chlorate of potassa is objectionable, because, except in particular cases, *perfect combustion* cannot be ensured by it; that is, the evolved gas is too suddenly generated, and is never perfectly *inodorous*, and in these analyses there should not be the smallest residuary vestige of the organic product appreciable by the empyreumatic smell of the produced carbonic acid or aqueous vapour.

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* I have not space here to go into the many details connected with this difficult subject, which, indeed, can only be learned in the laboratory: my object is to give the reader such an outline of the proceedings as may prevent the necessity of recurring to them in the individual analyses that I shall afterwards have to refer to, and may render the *data* upon which they are founded intelligible. The fifth volume of Dumas' *Chimie appliquée aux Arts*, may be profitably consulted for more minute particulars; as also, the authors to which I refer in the text.

To avoid these imperfections of this method, Gay Lussac suggested the employment of *oxide of copper* as a source of oxygen for the combustion, and it has the advantage of resisting decomposition when heated alone, whilst it readily yields oxygen to carbon and hydrogen, at high temperatures; so that by weighing it before and after the analysis, the quantity of oxygen imparted to the combustible may, if requisite, be determined. The analysis, therefore, as now practised, consists in mixing the organic matter in due proportion with oxide of copper, and so subjecting it to combustion, that the carbon may be entirely converted into *carbonic acid*, and the hydrogen into *water*. When nitrogen is present it is collected in the state of *gas*, and the proportion of oxygen is estimated by the deficiency in the joint weights of the carbon, hydrogen, and nitrogen, as compared with the original weight of the portion of the organic product subjected to analysis.

The oxide of copper is best obtained by heating copper-shavings to redness, exposed to air, and then bruising them in a mortar, by which the oxide is separated, and may be sifted off; or the plates may be successively quenched in water, when the scales of oxide fall off, and may be dried, powdered, and heated to redness. The oxide derived from the ignition of nitrate of copper is sometimes preferable, as being finer and lighter than the preceding; as these oxides are *hygrometric*, they should be kept in stopper-phials, and used warm, with as little exposure to air as possible.

The tubes used in these analyses should be of green glass, and generally about three-tenths of an inch diameter, and from 15 to 18 inches in length, sealed, and either drawn into a point, or rounded at the sealed end: the open extremity should be smoothed by fusion so as to receive a cork without danger of cracking; and it is generally proper to protect the tube, by rolling a strip of thick copper-leaf spirally round it, tied at each end by a piece of wire. It may be heated either by means of Cooper's lamp-furnace, (*Quart. Jour.*, xvii. 222,) or over charcoal, in a temporary arrangement of a grate and fire-bricks, (Faraday's *Manipul.*,) but all these arrangements must be left to the management of the operator, and require varying according to circumstances, only care must be taken that they are such as to enable us to heat successive portions of the tube at one time, and at another, to give its whole length a red-heat. (Dumas, v.) The whole of this process will essentially vary in its details according to the peculiarities of the product under examination, which, if *liquid*, requires also further modifications of the apparatus: for these I must refer to the details given by Dumas, and to a paper upon the subject by Liebig, in the 21st volume of Poggendorff's *Annalen*. If *solid*, three or four grains of it accurately weighed, and dried at 212° in vacuo over sulphuric acid, (see the means of effecting this described by Dr. Prout *Ann of Phil.*, vi. 272,) are mixed with about 200 grains of the oxide of copper, and introduced into the analyzing-tube, into the end of which is previously placed about half an inch in length of small copper-shavings superficially oxidized; these shavings should also occupy about two inches of the tube *above*, or as it lies horizontally, *before* the organic mixture, the object being to keep the whole contents of the tube in a loose or porous condition, so that the gaseous products may escape from it without impediment. Perhaps the annexed sketch may render this arrangement more intelligible, in which *a* represents the sealed end containing oxidized copper-turnings, or fragments of the oxide; *b*, the intimate mixture of the oxide with the organic substance, and *c*, the remaining portion of the tube containing turnings, or scales of oxide. In this case, the portion *c* is first heated to redness, and the heat is then gradually extended through *b* towards *a*, in such a manner, that all the products may have to traverse the heated oxide; for perfect and entire destruction of the matter subjected to experiment, is the essential part of the process. Let us now suppose that the organic substance under examination, is a ternary compound of hydrogen, carbon, and oxygen; it is obvious that the products will be *water* and *carbonic acid:* to ascertain the weight of the former, and thence the weight of the *hydrogen* required to form it, the products, as they escape from *d*, may be carried through a tube containing fragments of fused chloride of calcium, and accurately weighed; by this, the vapour of water will be absorbed, and the increase in the *weight* of the tube and its contents, will indicate its quantity: every 9 grains of increase are equivalent to 1 grain of hydrogen. In the following cut (fig. 240), *d* represents the end of the decomposing tube, (fig. 239,) to which is annexed the chloride of calcium tube *e*, from which issues the smaller tube *f:* the junction at *d* is made air-tight by perforated cork. The weight of the produced carbonic acid may be learned in two ways; either by collecting it in its gaseous state, and determining its bulk, and thence deducing its weight and that of the carbon which it contains; or by condensing it into a weighed solution of caustic potassa, and determining its quantity directly, by the increase of weight sustained by the solution. In the former case, the tube at *f*, (fig. 241,) is connected by the caoutchouc joint *g*, with the bent-tube *h*, the extremity of which terminates in the inverted graduated jar *i* filled with mercury.

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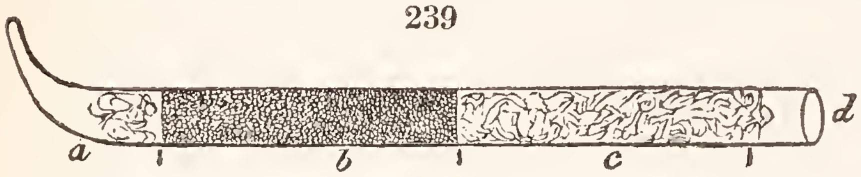

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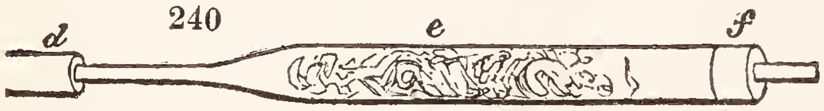

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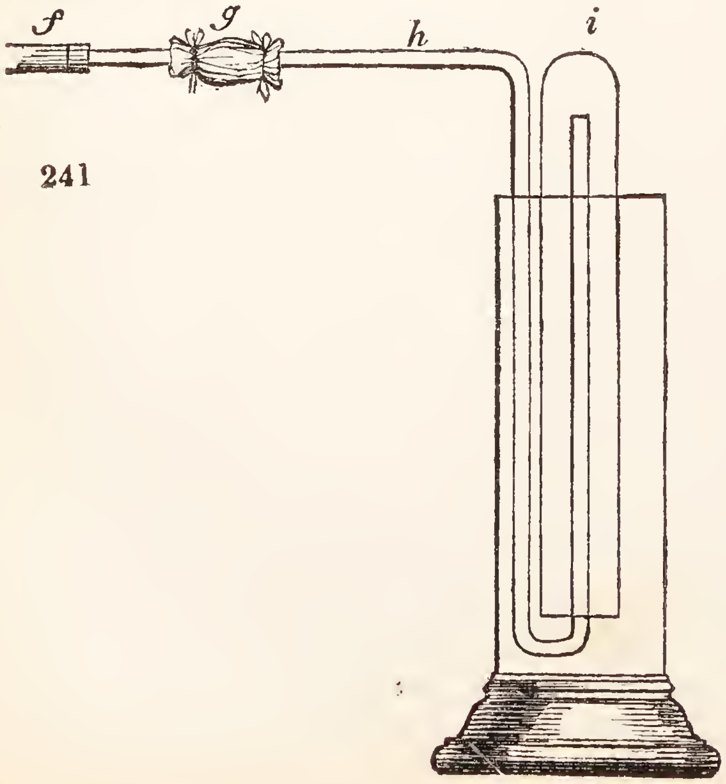

In the latter case, the carbonic acid gas may be conducted from the extremity of the chloride of calcium tube *f*, into the apparatus represented in the annexed cut (fig. 242), which is a glass tube blown into several thin bulbular enlargements, and containing a solution of caustic potassa. In figure, 243, this condenser is shown connected with the chloride of calcium tube *f*, by short lengths of caoutchouc piping, and having another tube *k*, containing fragments of fused potassa, attached in the same way to its other extremity. This latter tube is only required where *nitrogen* is to be collected, and even then, as I shall presently state, may be dispensed with*.

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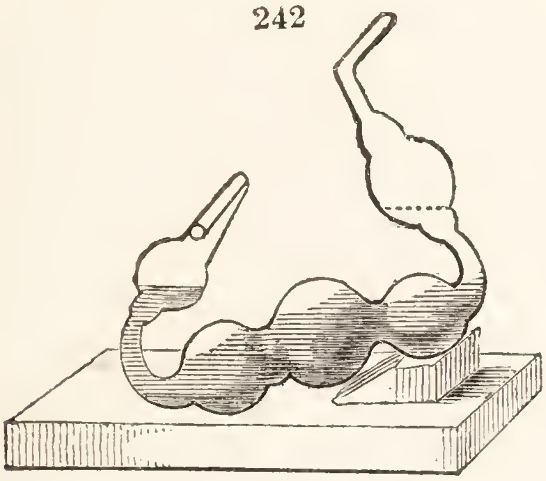

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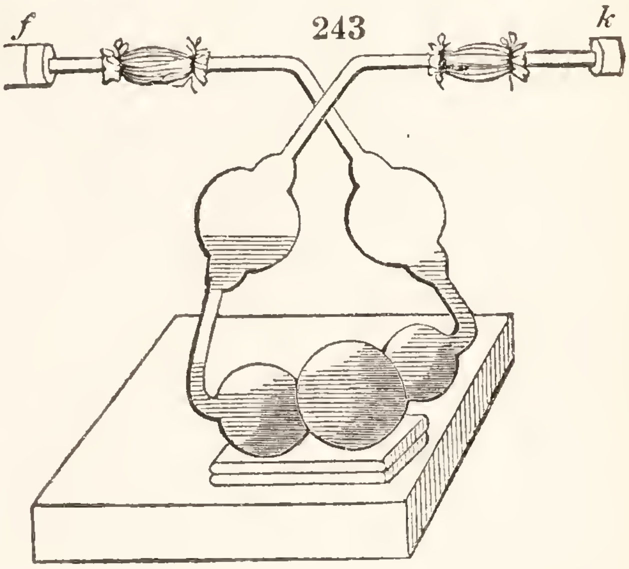

It will now, I think, be obvious, that after the abstraction of the *water*, in the chloride of calcium tube, the carbonic acid will pass on into the solution of caustic potassa, through which, by properly inclining the apparatus, it may be made to pass in divided bubbles, and under some pressure, so as to ensure its total absorption. When the experiment is completed, the apparatus is allowed to cool, and in order to prevent any portion of the alkaline solution retrograding into the chloride tube, the tip of the analyzing-tube near *a*, (fig. 239), is broken off, and any residuary carbonic acid may then be drawn into the alkaline solution, by applying gentle suction at the end of the tube *k*. (fig. 243.) The *weight* of the evolved carbonic acid is determined by accurately weighing the condenser with its alkaline solution, before and after the experiment.

When *nitrogen* is a component of the organic matter under examination, the mixture with oxide of copper is made as usual, but the contents of the fore-part of the analyzing-tube, *c*, (fig. 239,) must now consist of a mixture of shavings or filings of metallic copper with the oxide, and great care must be taken slowly to conduct the evolved gases through this mixture, rather highly heated, in order to effect the complete evolution of the nitrogen, and to decompose the various compounds which that substance might possibly form with the oxygen, carbon, or hydrogen. The nitrogen then escapes through the tube *k*, (containing fragments of caustic potassa, or of chloride of calcium, to deprive it of humidity,) and must be collected over mercury by connecting the end of that tube with the apparatus *g*, *h*, *i*, (fig. 241.) It is, however, in general, better, in cases where the analysis is complicated by the presence of nitrogen, to make a separate experiment for the determination of its quantity: in that case, the evolved gases (carbonic acid and nitrogen,) may be collected in the mercurial apparatus, and the carbonic acid abstracted by a few fragments of fused hydrate of potassa, when the nitrogen will remain, and its weight may then be inferred from the accurate determination of its bulk.

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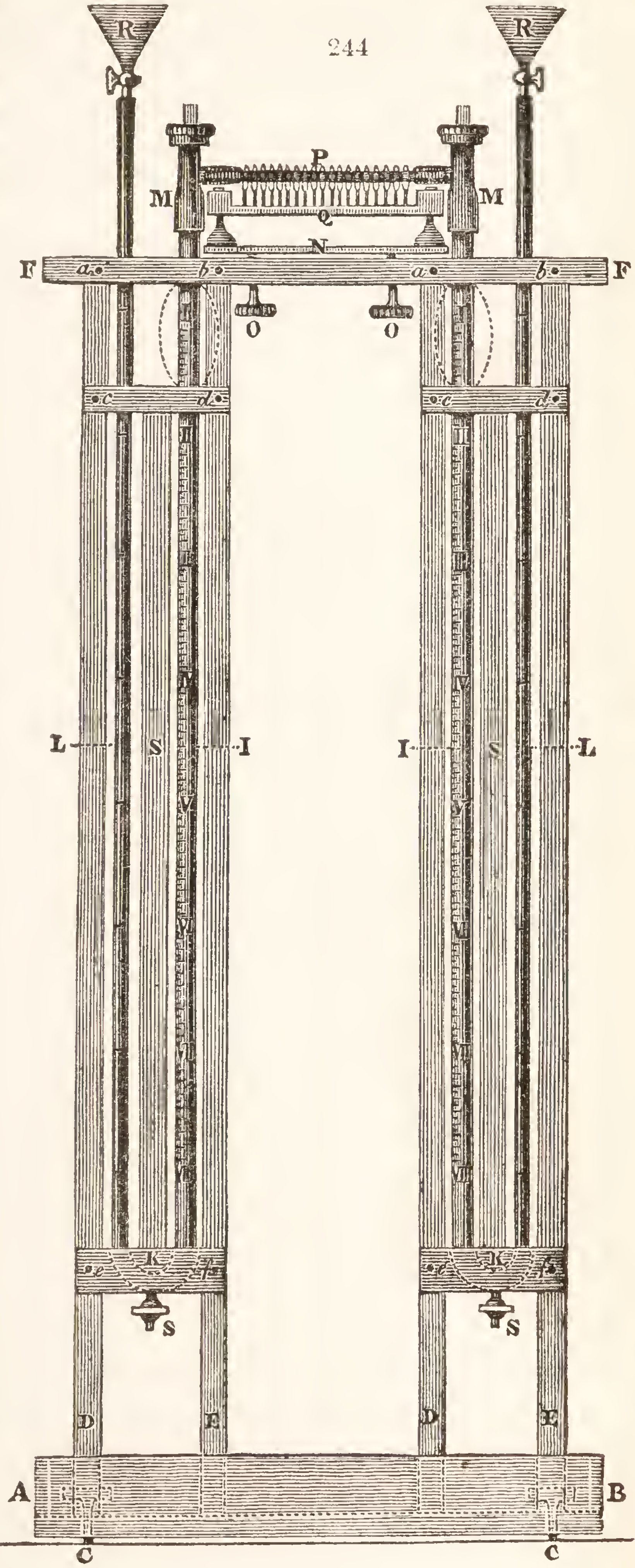
* This useful apparatus is the contrivance of Justus Liebig. (*Pogg. Ann.*, xxi.)

My object in the preceding details, has been to render the *principles* of the ultimate analysis of organic products intelligible to the student; the manipulations, in all their details, scarcely admit of useful description, and can only be learned by practice; and the beginner will, I think, do well, to make each element the object of a separate experiment; I mean, to employ one portion of the matter under examination for the determination of the quantity of water formed, or of the elementary hydrogen; another for the determination of the quantity of carbonic acid formed, or of the elementary carbon; and another for the nitrogen. The most experienced and dexterous chemist will also require repetitions of his analyses; and in undertaking these, he will do well to follow the recommendation of Dumas, who advises that these experiments should be made upon each substance in increasing quantities; one, for instance, upon *two*, one upon *four*, and one upon *six* grains; or in some such proportions.

I shall conclude these observations upon the ultimate analysis of organic products, with the following abstract from Dr. Prout's paper upon this subject, (*Phil. Trans.*, 1827,) which will elucidate some of the points that may appear obscure in the preceding paragraphs, and further explain some manipulatory details. Dr. Prout's object was, effectually to burn the organic substance in oxygen gas; in which case, supposing it to contain three elements, hydrogen, carbon, and oxygen, one of three things happens. 1. The original bulk of the oxygen gas *remains the same*, in which case *the hydrogen and oxygen in the substance exist in it in the same proportions in which they exist in water:* or, 2. The original bulk of the oxygen is *increased*, in which case the oxygen exists in the substance in a *greater* proportion than it exists in water; or, 3. The original bulk of the oxygen is *diminished*, in which case the *hydrogen predominates.*

Hence, in the first of these cases, the composition of a substance may be determined by ascertaining the quantity of *carbonic acid gas* yielded by a known quantity of it; while in the other two, the same can be readily ascertained by the same data, and by noting the excess or diminution of the original bulk of the oxygen.

Fig. 244, represents a front view of Dr. Prout's apparatus, for the determination of these points. AB is a platform, two feet square, surrounded by a ledge for preserving any mercury that may fall about, and furnished with four adjusting screws (of two of which, CC, are sectional views.) Into this platform are fixed perpendicularly four pillars, DE, DE, about four feet and a half high, supporting another small platform, FF, about four inches wide, and which may be fixed or removed at pleasure by the brass pins, *ab*, *ab*. II are glass tubes, graduated to hundredths of a cubic inch, and cemented at bottom into semicircular iron tubes enclosed in the blocks KK (as represented by the dotted lines.) These iron tubes project a little below the wood at the lower part, where they are furnished with iron stop-cocks, SS, for drawing off the mercury when it may be necessary. Into the other end of these semicircular tubes are likewise cemented the glass tubes, LL (of smaller dimensions, and a little longer than the tubes II), and forming with them, when taken together, inverted siphons. The smaller tubes, LL, are surmounted by funnels, RR, furnished with stop-cocks, the object of which is to permit the mercury to flow into them with any velocity that may be required. On the tops of the larger tubes, II, are cemented the vertical stop-cocks, MM, of which fig. 245 is a sectional view on a larger scale, and which renders the construction so obvious, that perhaps no further remark is necessary, than merely stating that the cup *a* is filled with oil, and that the plug, *b*, which is square at the upper part, and adapted to a key, is furnished with a shoulder, on which the screw-cap, *c*, rests, and by means of which it may be tightened at pleasure*.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On the platform, FF, (fig. 244,) is a thin piece of wood, N, capable of being raised or depressed by the screws, OO; on this the lamp, Q, is placed, at any distance that may be required from the tube P. Fig. 246 is an enlarged view

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[*] The syphons are fixed together independently of the general frame-work, and may be removed at pleasure by taking out the pins *cd*, *cd*, and *ef*, *ef*. This admits of their being replaced by others of different sizes. Those of a larger size have balls near the top, as represented by the dotted lines, and may

of this lamp; it consists of two reservoirs, *d e*, for holding the spirit, connected together by means of the tube, *f*, into which are placed, at the distance from one another of about $\frac{1}{3}$ of an inch, a number of vertical burners, *g g*, about one-twelfth of an inch in diameter, and $\frac{3}{4}$ of an inch long, and *made as thin* as possible, with the view of preventing the conduction of the heat. These burners are each furnished with a few threads of cotton, and are bent a little alternately like the teeth of a saw, in order that their flame may envelop the tube P, (fig. 244,) more completely: *h* is a cover for the wick of the lamp when not in use. The tube P, (fig. 244) is of green or bottle glass, moderately stout, and about one-fifth of an inch internal diameter. It is fixed between the horizontal parts of the vertical cocks, M M, so as to be perfectly air-tight; and when required, the whole, or any part of it, may be heated by means of the lamp, Q, at the pleasure of the operator.

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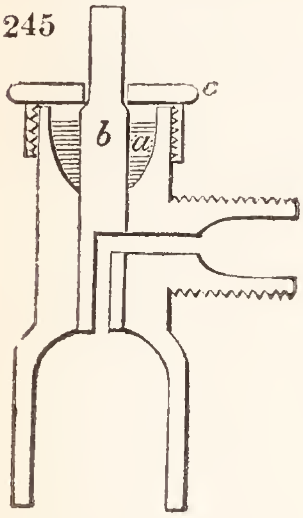

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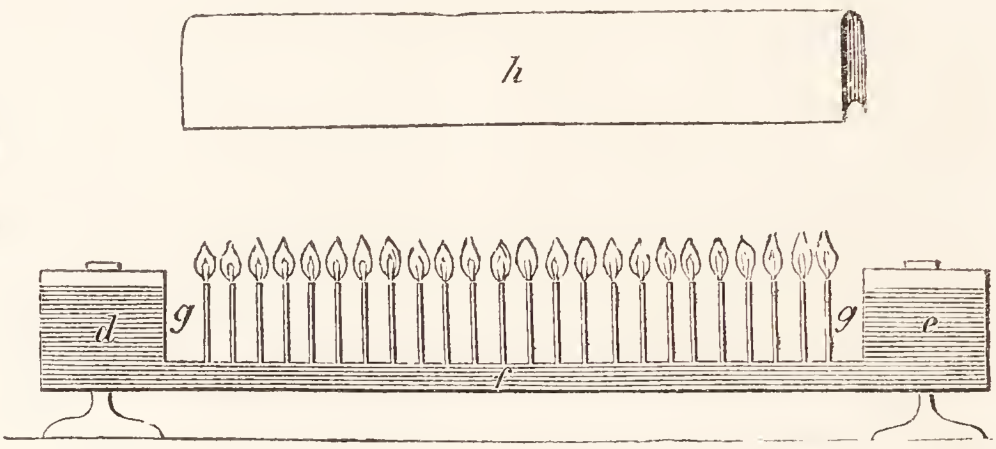

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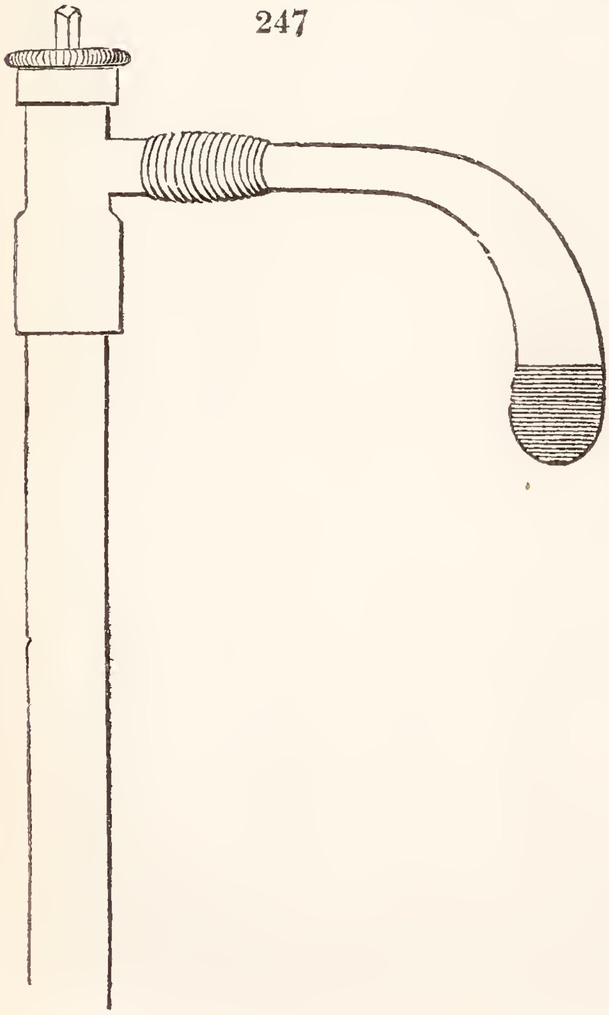

When the apparatus is to be employed, both the siphon-gasometers, IL, IL, are to be filled with quicksilver, and a small green-glass retort, containing the requisite quantity of chlorate of potassa (previously heated so as to expel the common air, and fill it with oxygen) is to be attached to one of the cocks, as represented in fig. 247, by means of a caoutchouc tube. Heat is then to be applied, and any quantity of oxygen gas that may be required, introduced into the tube I. After the whole has acquired the temperature of the atmosphere, the exact quantity of the gas

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contain as much as 20 cubic inches of gas. It much facilitates the process of determining the exact quantity of gas contained in the apparatus, to have both legs of the siphon graduated, which may be easily done so as to obviate the effects of capillary attraction when the tubes are not both of the same calibre.

is to be accurately noticed, as well as the state of the barometer and thermometer at the time. The tube P, containing the substance to be analyzed, is then to be firmly fixed between the cocks MM*, and subjected to heat, during which the oxygen gas is to be transferred from one siphon to another, through the red-hot tube, with any velocity that may be required, and which may be regulated by means of one of the stop-cocks of the funnels, RR, and the stop-cock, S, of the opposite siphon.

Such is a general view of the apparatus, and the principles of its operation; but perhaps a few practical remarks on some of the circumstances to be attended to during its employment, may not be deemed superfluous.

The substance to be analyzed may be placed in a small tray of platinum-foil, and introduced alone into the tube P, and gradually submitted to the action of heat and oxygen gas; but this does not answer well with organic compounds, as a portion of them is apt to escape combustion Another method is, to mix the substance with pure siliceous sand, and to retain the mixture in the centre of the tube by means of asbestos. But this method often fails, except there be about an inch of the oxide of copper at each end of the tube, which must be kept red-hot during the experiment, and in this case it succeeds completely with many substances. Another method, and that which the most generally succeeds, is to mix the substance with oxide of copper, to heat these together in the tube, in the first place, and afterwards to open the other stop-cock and send the oxygen gas through the ignited and partially reduced oxide, by means of which it again becomes peroxidized; and any portion of the substance that had escaped complete combustion in the first part of the experiment, is now completely burnt. This last method is also that employed when it is required to determine the quantity of carbonic acid gas yielded by a given quantity of any substance; only in this case, of course, oxygen gas is not required, and the contents of the tube P, must be taken out and well triturated, and subjected to heat a second time. If it should be required to analyze the gas formed, one method of removing

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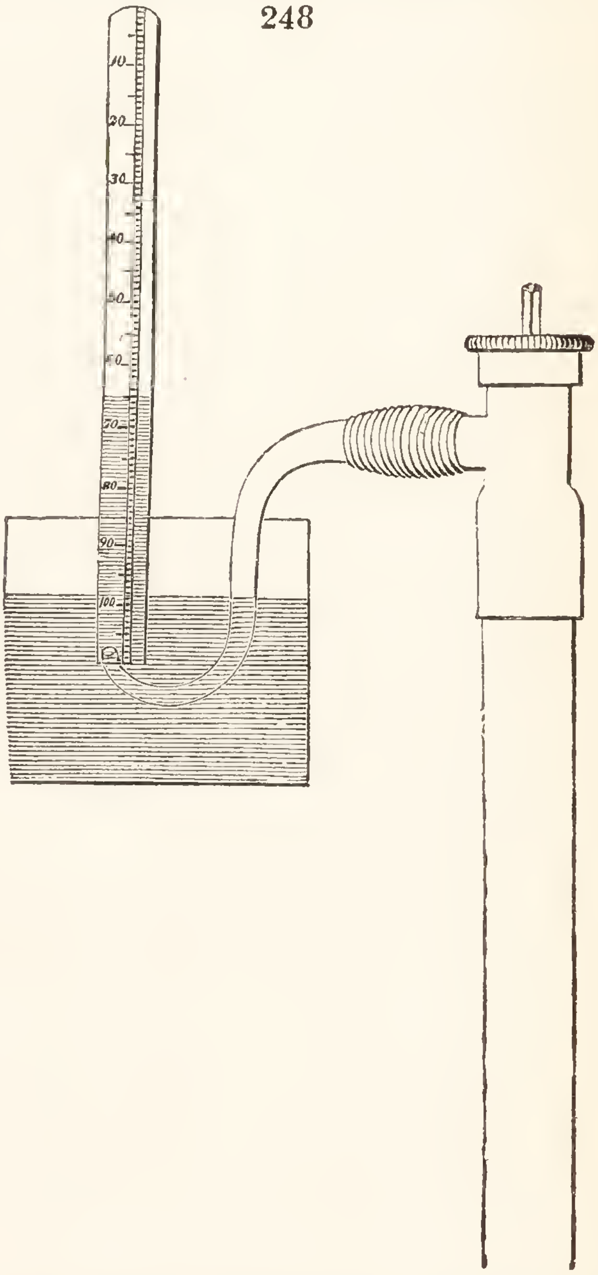

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* I have tried various modes of connecting the tube so as to ensure its being air-tight. Caoutchouc answers very well; but the best substance are slips of thin moistened hogs' bladder, tied on very tightly with fine *dry* twine. The twine is then to be moistened also, and the whole kept in this state till the end of the experiment.

it from the tube, I, is represented at fig. 248; and others will readily occur to the practical chemist.

The following are some of the advantages of this apparatus, and mode of analyzing organic compounds. In the first and chief place, *there is nothing to be apprehended from moisture.* Whether the substance to be analyzed be naturally a hydrate, or in whatever state it may be with respect to water, the results will not be affected; and the great problem, whether the hydrogen and oxygen exist in the substance in the proportions in which they form water, or whether the hydrogen or oxygen predominates, will be equally satisfactorily solved, and that (of course within certain limits), independently of the weight of the substance operated on*. When, however, it is the object to ascertain the quantities of carbonic acid gas and water yielded by a substance, it is, of course, necessary to operate on a known weight; but this being once determined, there is no fear, as in the common methods, of exposing the substance to the atmosphere as long as may be necessary. The hygrometric properties of the oxide of copper, as well as its property of condensing air, are also completely neutralized, for the whole, at the end of the experiment, being left precisely in the same state as it was at the commencement, the same condensation of course must take place, and any little differences that may exist are rendered quite unimportant from the bulk of oxygen gas operated on, which of course should, in all instances, be considerably greater than that of the carbonic acid gas formed. Another advantage of this method is, that perfect combustion is ensured by it. There is also no trouble of collecting or estimating the quantity of water, a part of the common process attended with much trouble, and liable to innumerable accidental errors, besides those already mentioned, and which there is no method of obviating or appreciating; here, on the contrary, the results are obtained in an obvious and permanent form, and, from the ease with which they are thus verified, comparatively very little subject to error.

The form and principles of this apparatus render it well adapted for many other chemical operations besides the analysis of organized substances. Such, for example, as the reduction of oxides by hydrogen, and a variety of others that will readily occur to the practical chemist.

In the course of the following pages, many instances will occur of the different modes of expressing the ultimate composition of organic bodies, depending, as the following examples will show, upon the particular view which may be taken of the secondary combinations of the elementary principles.

It is customary with many chemists to represent the oxygen and hydrogen in certain vegetable substances, by the term *water*, and hence, where these elements are in the ratio to each other of 8 and 1, and in union with carbon only, the expression *hydrate of carbon*, is sometimes applied to the compound. In the following table, which contains the results of the ultimate analyses of several organic compounds, by Gay Lussac and Thenard, the meaning of this expression will be evident, and also of the terms, excess of hydrogen, and excess of oxygen, as applied to such ternary compounds, in which, as will be observed, nitrogen is not present.

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* It is to be observed that, throughout the experiments, great care is taken that the gases are *saturated with moisture;* the errors from this cause are thus rendered definite, and are easily corrected by tables calculated for the purpose.

SUBSTANCES ANALYZED.	Carbon.	Oxygen.	Hydrogen.	Or supposing the Oxygen and Hydrogen to be in the state of *Water*.		
				Carbon.	Water.	Excess of Oxygen.
Sugar	42.47	50.63	6.90	42.47	57.53	0
Gum Arabic . .	42.23	50.84	6.93	42.23	57.77	0
Starch	43.55	49.68	6.77	43.55	56.45	0
Sugar of milk. .	38.825	53.834	7.341	38.825	61.175	0
Lignin of Oak . .	52.53	41.78	5.69	52.53	47.47	0
,, of Beech .	51.45	42.73	5.82	51.45	48.55	0
Mucous acid . .	33.69	62.67	3.62	36.69	30.16	36.15
Oxalic acid . .	26.57	70.69	2.74	33.57	22.87	50.56
Tartaric acid . .	24.05	69.32	6.63	24.05	55.24	20.71
Citric acid. . .	33.81	59.86	6.33	33.81	52.75	13.44
Acetic acid . . .	50.22	44.15	5.63	50.22	46.91	2.87
						Hydrogen in excess.
Resin (of turpent.)	75.94	13.34	10.72	75.94	15.16	8.90
Copal	76.81	10.61	12.58	76.81	12.05	11.14
Wax	81.79	5.54	12.67	81.79	6.30	11·91
Olive oil . . .	77.21	9.43	13.36	77.21	10.71	12.08

They consider it demonstrated, in reference to these experiments, 1st. That a vegetable substance is *acid*, when the oxygen which it contains is, to the hydrogen, in a proportion greater than is necessary to form water; or where there is *excess of oxygen*. 2nd. That a vegetable substance is *resinous*, *oily*, or *alcoholic*, where the oxygen is to the hydrogen in a less proportion than in water; or where there is *excess of hydrogen;* and, 3rd. That a vegetable substance is neither acid nor resinous, but *saccharine*, *mucilaginous*, &c., where the oxygen and hydrogen are in the same relative proportion as in water, or where there is *no excess of either*.

To the correctness of these results, there are, however, exceptions, some of which have been pointed out by Saussure (Thomson's *Annals*, vol. vi.), and by Daniell (*Journal of Science and Arts*, vi., 326); but we shall have again to refer to other analyses of the above important products. The vegetable principles, also, which include nitrogen, and among which are the *vegeto-alkaloids*, are not contained in the above table, so that, admitting the general *principle of classification*, it may be modified as follows, in reference to vegetable proximate principles :—

1. Triple compounds of carbon, hydrogen, and oxygen, in which the hydrogen and oxygen bear to each other the same relative proportion as in water, and which therefore are represented by $(car + q.)$

2. Similar triple compounds, in which there is excess of hydrogen; or $(car + q + h.)$

3. Similar triple compounds, in which there is excess of oxygen; or $(car + q + o.)$

4. Quadruple compounds of the above elements, with the addition of nitrogen, and represented by $(car + h + o + n.)$

5. There are also some important organic products belonging to the class of *hydrocarbons*, which will require much of our attention, and some of which, together with their general distinctive characters, have been already adverted to in the Section on Carbon. Although, therefore, it will be necessary often to digress from the arrangement of the vegetable proximate principles suggested by the above considerations, it may be resorted to as furnishing a general standard of reference.

But, the mere determination of the relative proportions of the ultimate elements of these proximate principles, is not the only difficulty which this branch of the science presents: they must be viewed in reference to the Atomic Theory, in such a way, as to ascertain what number of *elementary atoms* are probably contained in what may be termed the *proximate atom.* Let us, for instance, suppose the case of *tartaric acid:* it contains *per cent.* 36 carbon, 3 hydrogen, 61 oxygen, and is therefore represented in general terms by $(car + q + o)$, but how can its ultimate atomic composition be made to tally with its *proximate equivalent?* The proximate equivalent of *anhydrous* tartaric acid, deduced from the weight of it which saturates salifiable bases, is 66; if now, in reference to this equivalent, we consider it as constituted of 4 atoms of carbon, 2 of hydrogen, and 5 of oxygen, we shall obtain numbers closely corresponding with the experimental results; and which, therefore, we may presume to be the correct composition of its proximate atom. Again, in reference to *citric acid:* analysis gives us its component parts *per cent.*, as 41.38 carbon, 3.45 hydrogen, 55.17 oxygen, and these relative proportions may be atomically represented by 2 atoms of carbon, 1 of hydrogen, and 2 of oxygen, which give the *proximate equivalent* 29. But then, *one* atom of any salifiable base, oxide of lead for instance, is neutralized, not by 29, but by 58 of citric acid; we therefore assume its elementary composition to be 4 carbon, 2 hydrogen, and 4 oxygen, $= 58$, which number coincides with its proximate equivalent, or combining proportion.

There is another very important but difficult consideration, arising out of these views of the ultimate composition of the organic proximate principles, which relates to the different views which may be taken of the manner in which the ultimate elements are arranged, or of the state in which they exist, in the original substance, before its decomposition. These views materially affect the perspicuity of our arrangements, as the following instance will serve to show. Ether and alcohol are, like the acids just alluded to, compounds of carbon, hydrogen, and oxygen, but only in different proportions: ether is constituted *per cent.* of 64.87 carbon, 13.51 hydrogen, 21.62 oxygen. Alcohol consists of 52.18 carbon, 13.04 hydrogen, 34.78 oxygen; now the relative bearings of these numbers are such, as admit of *ether* being regarded as a compound of 4 atoms of carbon, 5 of hydrogen, and 1 of oxygen; and *alcohol* of 2 atoms of carbon, 3 of hydrogen, and 1 of oxygen. But here, the carbon and hydrogen, and the oxygen and hydrogen, are to each other in such proportions as to admit of our considering *ether* as a compound of 2 atoms of *bihydrocarbon* (or olefiant gas), and one atom of *water;* and *alcohol* as a compound of 1 atom of *bihydrocarbon* gas, and 1 of *water;* hence we have

Ether $= 2({}_2h + {}_2car) + q =$ dihydrate of bihydrocarbon.
Alcohol $= ({}_2h + {}_2car) + q =$ hydrate of bihydrocarbon.

But there is another way of viewing the composition of these bodies, which consists in regarding *quadrihydrocarbon*, and not bihydrocarbon, as the form of hydrocarbon present in them, and then *ether* would be a compound of 1 atom of quadrihydrocarbon and 1 of water; and *alcohol*, a compound of 1 atom of quadrihydrocarbon and 2 of water. Or,

Ether $= ({}_4h + {}_4car) + q =$ hydrate of quadrihydrocarbon.
Alcohol $= ({}_4h + {}_4car) + {}_2q =$ bihydrate of quadrihydrocarbon.

A third view of the atomic nature of alcohol and ether is this; a hydrocarbon distinct from any of those already described, (see pp. 480, et seq.,) and composed of 5 atoms of hydrogen + 4 of carbon, (the *Ethule* of Berzelius,) is the basis of ether and of alcohol: *ether* is an *oxide* of such hydrocarbon, and *alcohol* a *hydrated oxide*. Or,

Ether $= ({}_5h + {}_4car) + o =$ oxide of ethule.
Alcohol $= ({}_5h + {}_4car + o) + q =$ hydrate of ether.

I might go on to show other theoretic views which may be taken of the atomic constitution of ether and alcohol, and also to apply the same mode of reasoning to the probable proximate arrangements of the ultimate elements in a variety of other organic compounds; I have selected the above, as sufficient to point the student's attention to the importance of the subject, and as instances to which I shall afterwards have occasion to refer: the present state of organic chemistry does not admit of many such generalizations; such as may be safely adopted, I shall afterwards detail; many are too hypothetical to come within our limits; but the whole subject is of extreme interest, as promising to simplify the apparent confusion and complexity that prevail in reference to the relative proportions of the ultimate elements of organic products, and to enable us to group, or combine them under secondary forms, in many instances analogous to the binary arrangements of inorganic nature; and to apply to them an equally perspicuous nomenclature.

It is obvious, that by adopting any of the above definitions of ether and of alcohol, we acquire considerable facility in discussing their combinations, and mutual conversion into each other, and that the terms *hydrate* and *binhydrate of quadrihydrocarbon*, imply much more than the mere per centage statements of the elements: to illustrate this by a parallel case from inorganic chemistry; suppose a compound the ultimate elements of which are stated to be, *per cent.*, 15.35 carbon, 41.05 oxygen, 7.75 hydrogen, 35.85 nitrogen; this statement will be found compatible with, 1 atom of carbon, 2 of oxygen, 3 of hydrogen, and 1 of nitrogen; but how much is this statement simplified, and how different its meaning, by so grouping the carbon and the oxygen as to represent *carbonic acid*, and the nitrogen and hydrogen to represent *ammonia;* the whole producing *carbonate of ammonia*, or,

Carbon	1	6	15.35	Carbonic acid	1	22	56.4
Oxygen	2	16	41.05				
Hydrogen	3	3	7.75	Ammonia	1	17	43.6
Nitrogen	1	14	35.85				
	1	39	100.00		1	39	100.0

I shall have to adduce many similar instances derived from organic analyses, amply supported by experiment and analogy; and, as already remarked, importantly elucidating and simplifying these complicated researches.

I now proceed to an enumeration of the principal *proximate elements*, or *immediate principles*, of the vegetable kingdom; to the methods of separating them from each other, and of obtaining them in their insulated states; to an examination of their properties and uses; and to such views of their ultimate constitution as are founded upon researches carried on in reference to the preceding details. I cannot adhere strictly to the systematic arrangement above proposed, but it will constitute the foundation of the order in which they are enumerated. The immediately ensuing sections, therefore, of this chapter, will relate to those proximate principles in which the ultimate elements are so combined as to constitute *hydrates of carbon*, and I first select those which are of most common and general occurrence; I shall refer, as we proceed, to certain of their varieties or species, which belong to distinct *genera* of plants.

§ III. Gum, Mucilage, and their Varieties. Pectin and Pectic Acid. Mucic Acid and Pyromucic Acid.

Under the term *gum* are included several modifications of a distinct proximate principle of vegetables, which are of extremely common and almost universal occurrence. To some of these the term *mucilage* is occasionally applied; and all the varieties may be referred to one or other of these species, *gum-arabic* furnishing a characteristic specimen of gum, and *gum-tragacanth* of mucilage; the former the produce of the *Acacia vera;* the latter of the *Astragalus tragacantha.*

Gum occurs in the form of an exudation upon the bark of trees, and collects into drops which gradually harden by exposure, and of which gum arabic furnishes a very perfect example: it may also be discovered, more or less abundantly, in the sap and juices of almost all plants and fruits, where it is recognised by the properties we are about to describe.

Gum Arabic occurs in rounded pieces, or *tears*, of various sizes; and when pure is brittle, transparent, colourless, tasteless, inodorous, and of a specific gravity varying between 1.30 and 1.50. It does not crystallize, but when its aqueous solution is slowly evaporated, it remains in a hydrated state, and, though apparently dry, retains about 17 *per cent.* of water, which is given off by desiccation in vacuo over sulphuric acid at 212°. Heated above 212° it becomes yellowish, and slightly sour; and when subjected to destructive distillation, yields acid water, empyreumatic oil, carbonic acid, and carburetted hydrogen, and leaves a spongy residue of charcoal.

Gum is slowly soluble in cold water, and more rapidly in boiling water, yielding a mucilaginous solution, which is more or less viscid and clammy according to the proportion of gum held in solution. This solution is sometimes used as a glaze or varnish, and to give a gloss and stiffness to ribands, calico, &c. When substances, in a state of minute mechanical division, are suspended in it, it prevents their subsidence; hence its employment as an ingredient of writing-ink, and of some paints.

It is quite insoluble in absolute alcohol and in ether; hence alcohol occasions a white precipitate of hydrated gum, when added to its aqueous solution.

When powdered gum-arabic is triturated into a paste with *sulphuric acid*, the mixture gradually becomes brown, and if, after it has stood for 24 hours, it is diluted with water and saturated by chalk, so as to abstract the acid, the gum retained in solution is somewhat modified, and resembles that which we shall afterwards describe as produced by the action of sulphuric acid upon lignin. Heated with sulphuric acid, gum is decomposed, sulphurous acid, and traces of acetic acid, and of artificial tannin are formed, and about 30 *per cent.* of carbon deposited upon the addition of water. Boiled with *very dilute* sulphuric acid, it is partially converted into sugar. *Nitric acid* decomposes gum, and, when aided by heat, nitric oxide is evolved, and from 14 to 26 *per cent.* of mucic acid deposited on cooling. Longer digestion produces malic and oxalic acid. It would appear, from Vauquelin's experiments, that when chlorine is passed through a solution of gum, a portion of citric acid is generated, but this requires verification. Powdered gum absorbs chlorine, and becomes brown and soft; it also absorbs muriatic acid, becoming brown, viscid, and evolving the gas when acted on by sulphuric acid. Iodine is apparently without action upon gum.

The action of *salifiable bases*, and of *salts*, upon gum, has been inquired into by Berzelius, Pfaff, Bostock, Thomson, and several other chemists. According to Berzelius, a concentrated solution of gum is first coagulated by caustic potassa, and then gradually liquefies, and alcohol throws down from the solution a compound of gum and potassa in the form of a curdy precipitate, which, when dried, is brittle and soluble in water: similar combinations may be made with the other alkalis and alkaline earths. When a solution of gum is digested with finely-powdered oxide of lead, or with the recently-precipitated hydrated oxide, a definite compound of gum and oxide of lead is formed: the same compound is obtained by adding subnitrate or subacetate of lead to a solution of gum, or by adding ammonia, not in excess, to a mixed solution of gum and nitrate of lead; it is white and insoluble, and when carefully dried consists of 61.75 gum, and 38.25 oxide of lead. A solution of *gum-arabic* is precipitated by silicate of potassa; it is coagulated by a solution of borax, and the coagulum is soluble in free acid: in this respect gum resembles starch, but differs from mucilage. When persulphate of iron is dropped into solution of gum-arabic, a yellow gelatinous precipitate falls, soluble in free acid and in caustic potassa, but only partially soluble in boiling water. One part of gum in 1000 of water gives a yellow precipitate after 24 hours. This action upon persalts of iron is peculiar to gum-arabic. Protonitrate of mercury also affords a precipitate with gum. (Berzelius.)

The term MUCILAGE is applied to a modification of gum, of which the substance known in commerce as *gum-tragacanth* may be taken as the type. It is in the form of white or yellowish semitransparent flakes, or curled and crinkled pieces, and so tough as not to admit of being powdered till dried at 212°, when it loses about 10 *per cent.* of water, and becomes brittle. It does not dissolve like gum-arabic, but when steeped in water swells into a bulky mucilaginous mass, which, when boiled with water, gradually acquires the appearance of a solution of ordinary gum. According to Guerin, 100 parts of tragacanth yield 53. of *gum* (analogous to gum arabic), and 33 of *mucilage* (or *Bassorin*, a mucilaginous substance, described by Vauquelin as forming the bulk of gum Bassora, *Ann. du Muséum*, xvi., 167), the remainder being water and oxalate of lime.

GUM SENEGAL, CHERRY-TREE GUM (*Cerasin*), and that of *peach* and *apricot* trees, and other species of *Prunus*, together with the gum of starch and lignin, artificial products afterwards to be noticed, are closely analogous to gum-arabic, or become so when they are boiled with water. The mucilage of *quince-seed*, *linseed*, of the petals of the *marigold* (Geiger's *Calendulin*), and that of several of the gum-resins, partake of the generic characters of tragacanth, or of mixtures of gum and mucilage. *Sarcocolla* and *salep* also exhibit the same characters.

ULTIMATE COMPOSITION AND EQUIVALENT OF GUM. According to Berzelius's analysis of the insoluble and anhydrous compound of gum and oxide of lead (gummate of lead), the oxygen in the gum is to that in the oxide of lead as 12 to 1, and if we regard it as a *neutral compound*, it will consist of

				Berzelius.
Gum	1	186	62.5	61.75
Oxide of lead	1	112	37.5	38.25
	1	298	100.0	100.00

The ultimate composition of gum, therefore, as represented by Berzelius, is shown in the following table, together with the results of some other analysts (excluding a *trace* of nitrogen.)

				Berzelius.	Prout.	Gay-Lussac.	Berthollet.
Carbon	13	78	41.94	41.906	41.4	42.24	43.80
Hydrogen	12	12	6.45	6.788	6.5	6.93	6.86
Oxygen	12	96	51.61	51.306	52.1	50.84	49.24
	1	186	100.00	100.000	100.0	100.00	100.00

PECTIN; PECTIC ACID. Under this term (from πηκτὶς, *coagulum*), Braconnot has described the *jelly* of fruits, a substance which had generally been regarded as a compound of gum and vegetable acid: it had been distinguished from animal jelly by deficiency in nitrogen. It is obtained from many fruits, by carefully expressing their juice and evaporating it more or less, at a temperature not exceeding 212°. It may be obtained by the addition of alcohol to recently-expressed currant or gooseberry juice: in the course of a few hours a gelatinous substance separates, which must be washed with weak alcohol and dried: it then resembles isinglass in appearance, and, when digested in cold water, swells into a soft pulp like starch, but is not blued by iodine. When heated with a small quantity of potassa, or soda, or of their carbonates, it is converted into what has been termed *Pectic acid*. This acid is easily obtained by the action of alkalis on the ligneous tissue of some vegetables: it combines with bases, and may be again separated from them by other acids. (Braconnot, *Ann. de Chim. et Phys.*, xxviii. and xxx.) The *alkaline pectates* are soluble, but the *pectate of lime* is insoluble. It may be procured from the rasped roots of carrots and turnips; and deposited from a mixture of one-fourth of the juice of cherries and three-fourths of the juice of gooseberries, and, when washed carefully, first with dilute alcohol, and then with cold distilled water, is pure, with the exception of a little colouring-matter.

To obtain pectic acid from the carrot, the root is rasped, pressed, and washed with common water, until the latter passes off limpid. Every 100 parts of the pressed carrot, with 5 parts of bicarbonate of potassa, are boiled in water to form a clear fluid, and then again pressed; a strong solution of *pectate of potassa* is thus obtained, which, being decomposed by excess of solution of chloride of calcium, gives an insoluble *pectate of lime.* This, washed, and treated with water acidulated by muriatic acid, and finally with pure water, affords pure *pectic acid.*

In preparing it in this or any other way, water containing earthy salts should be carefully avoided, as they are decomposed, and precipitate it. It has been much recommended in France as a part of the diet of invalids, and is said to be an antidote against many of the poisonous salts. (*Ann. de Chim. et Phys.*, xxx., 96.)

Pectic acid has not been quantitatively analyzed, but pectate of potassa (neutral) is said to consist of 15 potassa + 85 pectic acid; so that the equivalent of the pectic acid would be about 270.

MUCIC ACID; SACLACTIC ACID. This acid is produced by the action of nitric acid upon *gum*, or upon *sugar of milk.* It was discovered by Scheele (*Opusc.*, ii., 3). It is obtained by heating in a retort about 3 parts of gum-arabic and 5 of nitric acid, diluted with half its weight of water; carbonic acid and nitrous gas are evolved, and when the effervescence has nearly ceased, the mixture is allowed to cool: it then deposits a white sediment, which is mucic acid: 1 part of *sugar of milk* may be substituted for the gum, and exactly the same product is obtained. It may be purified as follows: add ammonia, in slight excess, to the impure acid, and afterwards as much boiling distilled water as will dissolve the salt formed. Filter the solution while boiling-hot, and then evaporate it very slowly, nearly to dryness. The *mucate of ammonia* will be separated in the form of crystals, which are to be washed with cold distilled water till they become quite white and pure. They are now to be again dissolved in distilled water, and the boiling saturated solution permitted to drop from a filter into cold diluted nitric acid. This latter, of course, decomposes the mucate, and precipitates the acid in a state of purity. (Prout, *Phil. Trans.*, 1827.) This acid is sparingly soluble in water, requiring 60 parts, at 212°, and is deposited as the solution cools, in the form of a white gritty powder, of a slightly acid taste. It is insoluble in alcohol. It combines with the metallic oxides, and forms a class of salts called *mucates*, or *saclactates*.

The salts of this acid have been especially examined by Trommsdorff, who, with Berzelius, agrees in assigning to it the equivalent 105: according to these chemists the *mucate of lead*, which is insoluble in water, consists of

				Berzelius.	Trommsdorff.
Oxide of lead	1	112	51.61	51.66	51.5
Mucic acid	1	105	48.39	48.33	48.5
	1	217	100.00	100.00	100.0

The following are the analyses of the *mucic acid* in reference to this equivalent.

				Berzelius.	Gay-Lussac and Thenard.	Prout.
Carbon	6	36	34.29	33.430	33.69	33.33
Hydrogen	5	5	4.76	5.105	3.62	4.94
Oxygen	8	64	60.95	61.465	62.69	61.73
	1	105	100.00	100.000	100.00	100.00

Pyromucic Acid. When mucous acid is subjected to destructive distillation it yields about one-fifteenth of its weight of *pyromucic acid*, part of which sublimes, and part dissolves in the distilled liquid. The whole is dissolved in water, and filtered through animal charcoal, evaporated and crystallized, or again sublimed. This acid is permanent in the air, inodorous, very sour, fusible at 270°, and rises in vapour at a few degrees above that point, condensing in drops which concrete in fine acicular crystals, soluble in 26 parts of cold, and in less of boiling, water, and more soluble in alcohol. (Houton Labillardière, *Ann. de Chim. et Phys.*, ix., 365.) It consists, in its anhydrous or combined state, of

				Boussingault.
Carbon	10	60	58.3	58.74
Hydrogen	3	3	2.9	2.88
Oxygen	5	40	38.8	38.38
	1	103	100.0	100.00

The crystallized acid appears to include 2 atoms of water, and, according to Dumas, is isomeric with *pyrocitric acid*, and in its anhydrous state, with the *pyromeconic*.

The salts of this acid (*Pyromucates*) are almost all soluble: the only metallic salts which are precipitated by it being those of the peroxide of iron, protoxide of mercury, and of tin. It is as good a precipitant of the persalts of iron as succinic, or benzoic acid.

§ IV. SUGAR.

CANE SUGAR. HONEY SUGAR. GRAPE SUGAR. MANNITE. LIQUORICE SUGAR, OR GLYCYRRHIZIN. MUSHROOM SUGAR.

Sugar may be extracted from the juice of a number of vegetables, and is contained in all those having a *sweet* taste: that which is commonly employed is the produce of the *arundo saccharifera*, or *sugar-cane*, a plant which thrives in hot climates.

The constituents of *cane-juice* are

Water,
Sugar,
Gum,
Vegetable Mucilage,
Gluten,
Albumen,
Green Fecula,
Lignin,
Acetic Acid,
Malic Acid,
Acetate of Lime,
Acetate of Potash,
Super Malate of Lime,
Sulphate of Lime.

Crystallizable or Cane-Sugar. The art of making sugar consists in isolating the concrete sugar from all the substances with which it is associated in cane-juice, and the plan is as follows.

The cane, when ripe, is cut off at the root, stripped of leaves and ends, then passed twice through the mill, so as to express all the juice. To prevent fermentation, which commences most rapidly in new juice, a portion of lime (about 1 to 1600) is immediately mixed with the juice, which is then passed through a series of boilers to the last evaporating vessel called a *teache*. The syrup there is boiled until it granulates to *proof*, and is then transferred into coolers for the crystals to form and separate from the molasses or treacle; after which it is packed into hogsheads for exportation to this country, under the name of *muscovado* or *raw sugar*.

During the process of extracting *raw sugar* from the *cane-juice*, the saccharine matter is materially affected, its colour is darkened, and its power of crystallization considerably weakened.

When the sugar-cane has attained its full maturity for grinding, little or no colouring-matter is contained in the juice, but it exists in the waxy or resinous particles combined with the green fecula, which are left in the sugar, when the green fecula is precipitated by the lime. In boiling, the alkali sets free the colouring-matter, which is dissolved by high temperatures, and thus by the application of heat, Sugar, from its extraordinary solvent powers, suffers more or less at all temperatures.

By evaporating the cane-juice in open pans, the heat of the vessel itself is above 300° Fahr., and as the juice cannot support a temperature of 225° without decomposition of the green fecula and other vegetable matter, the saccharine matter must necessarily undergo great changes. Solid *anhydrous sugar* is made fluid at 300°, and at 302° is decomposed: the syrups are therefore darkened by the charring and carbonization of the juice at the bottom of the evaporating vessels. The saccharine matter thus decomposed is probably converted into gum. (Dr. Thomson describes sugar as differing from gum merely by containing an atom of water less. Hence an atom of sugar + an atom of water, constitute an atom of gum.)

In addition to the injurious effects of heat on the saccharine matter, there is another principle, opposed to crystallization, existing in the defecated juice, which is vegetable mucilage, and which, at a boiling temperature, is converted into a matter analogous to gum. Dr. Turner describes it most correctly. "The saccharine principle of *treacle* has been supposed to be different from crystallizable sugar: but it consists chiefly of common sugar, which is prevented from crystallizing by the presence of foreign substances, such as saline and other vegetable matters."

The process of Refining Sugar consists in separating the pure crystals from the uncrystallizable and colouring-matter existing in the sugar-cane, and subsequently increased on converting the *cane-juice* into *raw* or *Muscovado sugar*. The following is a sketch of the modern process by which sugar is *refined*: Raw sugar is chosen for the purpose by the sharpness and brightness of the grain, and those kinds are preferred which have a peculiar gray hue. Soft-grained yellow sugars, although whiter, are not so fit for refining, and it is for this reason that sugars from particular colonies are seldom used, such as those from the East Indies, Barbadoes, &c.

The proper sugar being selected, the *pans* are charged with a certain portion of lime-water, with which bullocks' blood is well mixed by agitation. They are then filled with the sugar, which is suffered to stand a night to dissolve. The use of the lime-water is to render the molasses more soluble, and thus to facilitate its separation from the pure solid sugar. In the purer kinds, and more especially when the refined is redissolved for the purpose of bringing it to its utmost degree of purity, lime is not used; the quantity of molasses being so small as to be easily removed by the agency of water alone.

Fires are lighted under the pans early in the morning, and when the liquid begins to boil, the albumen of the blood coagulates and rises to the top, bringing the impurities of the sugar with it. These are taken off with a skimmer. The liquid is kept gently simmering and continually skimmed, till a small quantity, taken in a metallic spoon, appears transparent: this generally takes from four to five hours. The whiteness of the sugar is not improved by this process, but even sometimes deteriorated, from the action of the fire; it only serves to remove foreign impurities.

The *colour* (as the refiners term it) or *whiteness* of the sugar when refined, depends in a great measure on the quantity of animal charcoal used in this part of the process. It is applied frequently to the first solution of the sugar and water. In some refining-houses the solution is filtered through beds of animal charcoal. The solution is, when perfectly bright and clear, run off into a large cistern.

The pans are then reduced to half their size by taking off their fronts, and a quantity of syrup returned into each, which is made to boil as rapidly as possible, till it is capable of being drawn into threads. Nothing but practice can ascertain the exact point at which the boiling should be stopped: if carried too far, the molasses is again bound up with the sugar; and if not carried far enough, much of the sugar runs off with the molasses in the after-process. When this point is ascertained, the fire is damped, and the boiling sugar carried to the *coolers:* a fresh quantity is then pumped into the pans, which is evaporated as before.

When the sugar is in the coolers, it is agitated with wooden oars till it appears granulated, and is no longer capable of being drawn into threads. It is upon this agitation in the cooler that the whiteness and fineness of grain in the refined sugar depend. The crystals are thus broken whilst forming, and the whole converted into a granular mass, which permits the coloured liquid saccharine matter to run off, and which would be combined with the solid if suffered to form in larger crystals. This granular texture likewise facilitates the percolation of water through the loaves in the after-process, which washes the minutely-divided crystals from all remaining molasses. That this is the true theory of the whitening of sugar by the process of refining, appears from a comparison with the process of making *candy*. In this latter, the raw material is cleared and boiled exactly in the same manner; but instead of being put into coolers and agitated, it is poured into pots, across which threads are strung, to which the crystals attach themselves; these are set in a stove, and great care is taken not to disturb the liquid, as upon this depends the largeness and beauty of the candy. In this state it is left for five or six days, exposed to a heat of about 95°, when it is taken out and washed with lime-water: this takes off the molasses from the outside, but a portion is combined in the crystals, and the consequence is, that candy is never whiter than the sugar from which it is made.

When the sugar has arrived at that granular state in the coolers, above described, it is poured into conical earthen moulds, which have previously been soaked a night in water. In these it is again agitated with sticks, for the purpose of extricating the air-bubbles which would otherwise adhere to the sugar and the moulds, and leave the coat of the loaf rough and uneven. When sufficiently cold, the moulds are taken to the upper floors of the manufactory, and the paper stops being removed from their points, they are set, with their broad ends upward, upon earthen pots. The first portions of the liquid molasses soon run down, and leave the sugar whitened by the separation. This self-clearance is assisted by a high temperature; and when it is perfected, pipe-clay, carefully mixed with water to the consistence of cream, is put upon the base of loaves to the thickness of about an inch: the water from this slowly percolates them; and, washing the solid sugar from all tinge of molasses, runs into pots. The clay is of no other use than to retain the water, and prevent its running too rapidly through the mass, by which too much of the sugar would be dissolved: a sponge, dipped into water, acts in the same manner. The process of *claying* is repeated four or five times, according to the nature of the sugar, and the degree to which it has been boiled. When the loaves are cleansed from all remains of the coloured fluid, they are suffered to remain some time for the water to drain off; when this is completed, they are set with their bases downwards, when all remains of it return from their points, and it is equally diffused throughout: they are then set in a stove, heated to about 95°, and thoroughly dried.

The *syrup*, or the mixed solution of sugar and molasses which runs into the pots, is mingled in the next boilings with the solution of raw sugar in the pans, and again evaporated. It is divided according to its fineness; the first running, containing most molasses, is reserved for the coarser loaves; whilst the last, being little else than a solution of sugar, is boiled into loaves, of the same degree of fineness as those from which it ran. The lowest syrups are boiled into what is called *bastard sugar*, from which the molasses runs with very little mixture of the solid sugar. This is called *treacle*, and is incapable of further crystallization.

The produce of 1 cwt. of raw sugar worked in this manner is, upon an average, 63 lbs. refined, 18 lbs. bastard, 27 lbs. molasses, 4 lbs. lost weight, dirt, &c., equal to 112 lbs.

The process above described may almost be considered as mechanical. The only truly chemical parts of it are the clearing with blood, and the use of lime-water, which combines with the molasses, and facilitates its solution during the percolation of the water.

It cannot be doubted that much improvement may be made in *refining sugar*, by the aid of chemistry, so as to produce a much larger quantity of *refined* from *raw sugar*, by extracting all the feculent and albuminous particles remaining in the raw sugar, and which, when again exposed to heat, at high temperatures, in the process of refining, further decompose the saccharine matter, and add still more to the molasses and mucilaginous matter enveloping the pure crystals in the raw sugar. The plan of refining by open pans is now nearly superseded in this country, by the application of steam, and Howard's plan of evaporating *in vacuo*, or at least under a greatly-diminished atmospheric pressure, by which exposure to any temperature, liable to injure the sugar, is effectually prevented. The process of *claying* is now generally omitted, and a strong solution of very white sugar is substituted. The principle is, that water, having a stronger affinity for the molasses than for the solid sugar, will percolate the crystals, carrying the molasses, and leaving sugar to enlarge and aggregate the crystals, rendering the *loaves* of more weight and closer grain.

In the boiling of sugar it is always desirable to avoid such elevation of temperature as may in any way tend to discolour or decompose it, and high-pressure steam, oil, and various saline solutions, have accordingly been resorted to as media for the communication of heat, the object being rapidly to boil and evaporate, without elevating the temperature to that point at which sugar suffers incipient decomposition. According to Dr. Henry, "a mixture of one part of water and three of sugar boils rapidly at 230°; and from this to 240° is its due temperature. If a solution of sugar be further concentrated by the evaporation of water, the thermometer rises to 340°. The sugar then begins to turn black, and at 370° it takes fire, on applying flame to its vapour, and burns strongly, leaving a residuum of charcoal."

Pure Sugar is a white brittle substance of a pure sweet taste. Its specific gravity is about 1.5 It is dissolved in its own weight of cold water, and boiling water dissolves a considerably larger quantity. This aqueous solution is called *syrup;* it is viscid, and furnishes crystals in the form of four and six-sided prisms, irregularly terminated, composed, according to Berzelius, of 100 sugar + 5.6 water. Sugar is soluble in alcohol, but more sparingly so than in water; when of the specific gravity of .830, it takes up about one-fourth its weight of pure white sugar; but absolute alcohol dissolves only about one-eightieth of its weight at its boiling-point, and on cooling, almost the whole separates in small crystals. When equal parts of strong syrup and alcohol are mixed, a quantity of small brilliant crystals of sugar are soon deposited.

Pure sugar is unchanged by air, and perfectly-pure syrup is not prone to change; but the addition of other vegetable substances, though in very minute quantity, materially influences the action of air on this solution. These, and other changes of such mixtures, we shall consider under the article *fermentation.*

Concentrated sulphuric acid decomposes sugar, evolving charcoal, and producing water and acetic acid. It is a striking experiment to mix about equal weights of strong syrup and sulphuric acid; the mixture, when stirred, presently becomes brown and black, then suddenly heats, effervesces, and passes into the state of an almost solid and very bulky magma of charcoal: the acid appears suddenly to abstract from the sugar the elements of water.

When sugar is dissolved in dilute sulphuric acid and long boiled, it is gradually altered and converted into that modification of sugar which is obtained by the action of the same acid upon starch. Nitric acid converts sugar into oxalic and other acids. (See *Oxalic Acid.*) Chlorine, and muriatic acid gas are absorbed by sugar; they render it brown and clammy; and chlorine yields muriatic acid, and apparently some malic acid. When 3 or 4 *per cent.* of oxalic or tartaric acid are added to sugar, it is rendered permanently uncrystallizable.

Sugar combines with the salifiable bases. The alkalis dissolve it, and destroy its sweet taste, which re-appears if an acid be added. When, however, they are left long in contact of sugar, they effect a more important change, becoming carbonated, and apparently converting the sugar into *gum*. Sugar absorbs ammoniacal gas, and forms with it, according to Berzelius, a definite compound of 1 atom of sugar, 1 of ammonia, and 1 of water, which, exposed to air, loses ammonia and leaves unaltered sugar. The hydrated alkaline earths are soluble in large proportion in syrup. When the solutions are evaporated, uncrystallizable gum-like compounds remain, insoluble in alcohol. From a solution of sugar and lime, Mr. Daniell obtained crystals of carbonate of lime and a portion of gum. The addition of phosphuret of lime to syrup produces an analogous change. (*Journal of Science and the Arts*, vi. 32.)

Syrup dissolves hydrated oxide of copper, and the carbonate and subacetate of copper, and forms blue or green solutions, from which alkalis do not throw down the oxide, but which are decomposed by sulphuretted hydrogen and by ferrocyanuret of potassium. Some of the cupreous salts are reduced, or afford precipitated suboxide, when boiled with sugar.

When oxide of lead is digested in a solution of sugar, it forms a yellow alkaline liquid, which, on evaporation, yields a tough deliquescent mass. But when a solution of sugar is boiled with excess of oxide of lead, and filtered whilst hot, it deposits, after some hours, bulky flakes of an insoluble tasteless compound, which may be dried without decomposition, in vacuo: it is soluble in the acids, and when diffused through water may be decomposed by a current of carbonic acid, which forms carbonate of lead, and the sugar is evolved. Berzelius considers this as a compound of 1 atom of sugar, and 2 atoms of oxide of lead: it consists of 42.35 sugar, and 57.65 oxide of lead.

When sugar is boiled with solution of nitrate of silver, a black powder is formed, which has not been examined: from perchloride of mercury it throws down the protochloride; and when mixed with solutions of peroxide of iron, the whole of the oxide cannot be precipitated by ammonia.

When sugar is exposed to a heat of 212° it undergoes no other change than that occasioned by the loss of adhering water; but at 300° it begins to fuse, becomes brown, evolves a little water, and is resolved at higher temperatures into new arrangements of its component elements. Dr. Prout found that sugar, exposed for seven hours to a temperature of 300°, only lost 0.6 *per cent.* of its weight, but its properties were permanently injured. If suddenly elevated to a temperature of about 500°, it bursts into flame.

In sugar, as in gum, the oxygen and hydrogen are to each other in the same relative proportions as in water, so that its ultimate composition is theoretically represented by $car + q$. But the relation of the carbon to the water, or the absolute equivalent of sugar, is not so easily determined, in consequence of the varieties of sugar differing a little in the relative proportion of carbon which they contain: if this be assumed at

40 *per cent.* then the carbon and water will be in the ratio of their respective equivalents[*], but there is, in the greater number of the analyses, an excess of carbon in reference to their equivalents, and in regard to the weight of the *proximate equivalent* of sugar, the only compound from which it can be deduced is that with oxide of lead. If the insoluble *saccharate of lead*, above described, be regarded as composed of 1 atom of sugar and 2 of oxide of lead, the number 162 will be the representative of sugar, and we may then adopt the following statement[†] of its ultimate composition.

				Berzelius.
Carbon	12	72	44.4	44.99
Hydrogen	10	10	6.2	6.41
Oxygen	10	80	49.4	48.60
	1	162	100.0	100.00

These are the results of the analysis of the *anhydrous sugar*, as it is presumed to exist in combination with oxide of lead: *crystallized sugar*, dried at 212°, is presumed to consist of

				Berzelius.
Anhydrous Sugar	1	162	94.74	94.7
Water	1	9	5.26	5.3
	1	171	100.00	100.0

or, in reference to *ultimate constituents*, crystallized sugar contains

				Berzelius.	Gay-Lussac and Thenard.	Döbereiner.	Crum.	Berthollet.	Ure.
Carbon	12	72	42.1	42.225	42.47	40.14	41.8	41.26	43.38
Hydrogen	11	11	6.4	6.600	6.90	7.05	6.5	6.97	6.28
Oxygen	11	88	51.5	51.175	50.63	52.81	51.7	51.77	50.33
	1	171	100.0	100.000	100.00	100.00	100.0	100.00	100.00

To these I subjoin Dr. Prout's analysis of several varieties of sugar[‡], designated as below. (Gmelin's *Handbuch.*)

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[*] Döbereiner regards crystallized sugar as a compound of 6 atoms of carbon, 6 of hydrogen, and 6 of oxygen, the carbon being equally divided between the hydrogen and oxygen, so as to form a *carbonate of hydrocarbon.*

[†] I have here omitted half an atom of hydrogen, which Berzelius' atomic numbers require.

[‡] The following is Dr. Prout's statement of the composition of the different grades of sugar. (*Phil. Trans.*, 1827.)

	Carbon.	Water.
Pure sugar-candy	42.85	57.15
Impure sugar-candy	41.5 to 42.5	58.5 to 57.5
East India sugar-candy (*v*)	41.9	58.1
English refined sugar	41.5 to 42.5	58.5 to 57.5
East India refined sugar (*v*)	42.2	57.8
Maple sugar (*v*)	42.1	57.9
Beet-root sugar (*v*)	42.1	57.9
East India moist sugar (*v*)	40.88	59.12
Sugar of diabetic urine	36 to 40 ?	64 to 60 ?
Sugar of Narbonne honey	36.36	63.63
Sugar from starch	36.2	63.8

[In these results *fixed* bodies only have been allowed for, and those marked (*v*), as occurring in commerce, are probably subject to slight variations in their composition.]

On

	A	B C	D	E	F G	H
Carbon	42.85	42.00	41.90	42.20	42.10	40.88
Hydrogen	6.35	6.44	6.46	6.42	6.43	6.57
Oxygen	50.80	51.56	51.64	51.38	51.47	52.55
	100.00	100.00	100.00	100.00	100.00	100.00

A Purified candy; B West India candy; C English refined; D East India candy; E East India refined; F Maple-sugar; G Beet-sugar; H East India moist.

Maple-Sugar is the produce of the *Acer saccharinum*, which is cultivated as a source of sugar in North America. A hole is bored through the bark in spring, from which the sap flows to such an extent, that a tree of average size yields about 50 quarts in 24 hours; it contains 5 *per cent.* of sugar. The sap is collected during 5 or 6 weeks: it is rapidly boiled down, and yields a coarse sugar, which, however, may be purified by the same processes as cane-sugar, and resembles it in its properties.

Beet-Sugar is obtained from the *Beta vulgaris.* The manufacture of sugar from beet-root has been successfully and extensively pursued in France: many interesting details respecting it will be found in a paper in the *Quarterly Journal*, xxi. 252. The roots, having been softened in water, are sliced, and the juice is expressed and boiled down to about two-thirds its bulk, with the addition of a little lime; it is then strained, again evaporated, and purified in the same way as cane-sugar. 100 lbs. of the root furnish between 4 and 5 lbs of purified white sugar, besides a quantity of syrup, at the average expense (in France,) of between threepence and fourpence a pound.

Granular Sugar. This modification of sugar, (the Krümel-zucker, crumbling or granular sugar of the German chemists), exists in the juice of several fruits, but especially in grapes, and may be produced artificially from lignin, starch, and some other substances which we shall afterwards describe: it may also be obtained from honey. *Granular sugar* forms the saccharine concretions that are found in raisins; and as it exists abundantly in the juice of the *grape* it is often termed GRAPE SUGAR. In good seasons the expressed juice of grapes contains from 30 to 40 *per cent.* of solid matter, the greater part of which is sugar: there is a small

On these Dr. Prout makes the following remarks: "The *sugar-candies* of the shops frequently contain minute quantities of foreign fixed bodies, such as lime, &c., as well as others of a destructible character. Both the specimens of *India sugar-candy* I examined were obviously impure to the eye, being of a brown colour, and deliquescent; they contained, among other things, traces of potash. The *East India refined sugar* was perfectly white, but rather soft and friable, and it did not possess the fine and brilliant grain of the best refined sugars of commerce. For a specimen of the *maple* sugar I was indebted to Mr. Faraday; this, when I received it, was very impure and deliquescent, but by treating it by the process above alluded to (see *Phil. Tr.*), a portion was separated that differed but little in its appearance from cane sugar. The *beet-root sugar* was made and refined in France; it was perfectly white, but rather soft and fine in the grain. The *East India moist sugar* was of a very low kind, and known in commerce by the name of *Burdwan sugar;* it was deprived of its hygrometric moisture before analysis by exposure to sulphuric acid under a receiver. The *diabetic sugar* was prepared as above; the results given were obtained many years ago, and I have had no opportunity of repeating the analysis with the present apparatus; I believe, however, that diabetic sugars, in general, belong to the honey variety. The *sugar of starch* was prepared by myself in the usual manner."

relative quantity of gum, extractive, gluten, and bitartrate of potassa. To obtain the sugar, the juice is neutralized by the addition of chalk or powdered marble, strained or filtered, mixed with a little white of egg, boiled, skimmed, and evaporated till of the specific gravity of 1.32. It is then allowed to cool, and in a few days it concretes into a solid mass, which is drained, and then dried by pressure: it affords about 3 parts of dry sugar and 1 of syrup. The sugar may be rendered white by boiling it with charcoal. (Proust.)

HONEY. The substance secreted in the nectaries of flowers, is collected by bees, and by them converted into honey and wax: the portion of sugar not required for nutriment is returned by the insect into the combs, in the form of a yellow syrup, the taste and smell of which differs a little, according to the flowers whence it has been derived, but which is always yellow, viscid, and very sweet. Honey contains two kinds of sugar; the one resembles that from the grape, the other is uncrystallizable: honey also contains a yellow colouring-matter, wax, gum, and sometimes manna-sugar. The solid sugar is most easily obtained from the granular or crystalline honey, by the action of strong alcohol, which dissolves the other ingredients, but leaves the granular sugar. It may be whitened by dissolving it in water, filtering, boiling with charcoal, and evaporating the solution till it granulates when cold.

GRAPE-SUGAR is less soluble in water than cane-sugar, and the syrup which it affords is less viscid. It does not sweeten so effectively as cane-sugar, and is less soluble in alcohol. When dissolved in boiling alcohol it is deposited in an irregularly-crystalline mass on cooling. Acids act upon it as on cane-sugar, but it has less affinity for salifiable bases; it combines readily with subacetate of copper; when its solution is mixed with common salt, dodecaëdral crystals may be obtained from it, consisting of 25 chloride of sodium, 75 sugar, and about 7 *per cent.* of water. Dry grape and honey sugar have been analyzed with the following results, as given by Gmelin.

				Grape Sugar. Saussure	*Honey Sugar.* Prout.
Carbon	6	36	36.36	36.71	36.36
Hydrogen	7	7	7.07	6.78	7.07
Oxygen	7	56	56.57	56.51	56.56
	1	99	100.00	100.00	99.99

The *sugar of malted grain*, of *diabetic urine*, and that formed artificially from *starch* and from *woody fibre*, has the general characters of grape-sugar: these we shall afterwards examine. A similar sugar has also been obtained from the Spanish chestnut, to the amount of about 14 *per cent.* from those grown in Tuscany. The French chestnuts are less saccharine.

MANNITE; MANNA-SUGAR. This species of sugar is most abundant in Manna, but is also found in beet-root, celery, asparagus, onions, and probably in many other sweet plants: it is also contained in the sap of the *larch* (and other species of *pinus*), and exudes from their bark, but it always tastes of turpentine. (*Manna Brigantina.*) Manna exudes from several species of *ash*, especially from the *Fraxinus ornus*, and *rotundifolia*. The best *flake-manna* is imported from Sicily and Calabria, it is of a buff-colour, light, and translucent. It has a slight odour, and a sweet, somewhat nauseous taste. Mannite is obtained from manna, by boiling it in alcohol: as the solution cools, it crystallizes: it may be purified by pressure. By very slow crystallization it furnishes delicate four-sided acicular prisms. It forms about four-fifths of the best manna; the residue is common sugar, and a peculiar yellowish extractive matter, in which the aperient quality of the manna resides.

Mannite is white, or nearly so, and very soluble in water: its aqueous solution, when sufficiently concentrated, concretes. Even when much diluted, it does not ferment; so that it may in this way be separated from the other varieties of sugar, for, when mixed with them, it remains undecomposed, whilst they are converted into alcohol.

The ultimate composition of mannite has not been satisfactorily determined, in consequence of the difficulty of ascertaining whether it does or does not contain chemically-combined water; nor is there any combination of it from which its proximate equivalent can be deduced. Gmelin gives the following view of its supposed atomic constitution.

	According to Prout.			According to Saussure.		
Carbon	15	90	38.46	7	42	48.27
Hydrogen	16	16	6.84	5	5	5.75
Oxygen	16	128	54.70	5	40	45.98
Dried at 212°	1	234	100.00	1	87	100.00

LIQUORICE-SUGAR. GLYCYRHIZIN. When a strong infusion of liquorice-root is slowly evaporated to a small bulk, and sulphuric acid added, a precipitate falls, containing sugar and albumen, which is to be washed with water acidulated by sulphuric acid, then with pure water, and afterwards digested in alcohol, which leaves the albumen. A solution of carbonate of potassa is then dropped into the alcoholic solution till its acid is neutralized; it is filtered and evaporated, and the sugar remains in the form of a yellow transparent mass, intensely sweet, and easily soluble in alcohol and water: it is characterized by its tendency to combine with acids, bases, and salts. With acids it forms difficultly soluble compounds. *Sulphate of glycyrhizin* is tough, and sweet without acidity; it dissolves in boiling water, and gelatinizes on cooling: its alcoholic solution is not precipitated by water. *Acetate of glycyrhizin* resembles the sulphate, but is more soluble, and forms a stiffer jelly. Glycyrrhizin combines with bases, and, when digested with alkaline carbonates, gradually displaces carbonic acid, and forms soluble compounds, which are not decomposed by carbonic acid. It occasions precipitates in most metallic salts. An analogous sugar has been found in the leaves of the *Abrus precatorius*, and in the root of the *Polypodium vulgare.* (Berzelius.)

MUSHROOM SUGAR was discovered by Braconnot in several species of *agaricus*, and other *fungi*, and by Schrader in *morels.* (*Helvella mitra.*) It is obtained by triturating the fungus with a little water, pressing it, and evaporating the expressed liquid nearly to dryness: the dry residue is digested in alcohol, and the solution yields crystals of the sugar on evaporation; they are square prisms, colourless when pure, slightly sweet, and less soluble than cane-sugar. Concentrated sulphuric acid forms with it a red solution, from which a white coagulum separates on the addition of water.

§ V. STARCH AND ITS VARIETIES. INULIN. LICHENIN, ETC.

STARCH, or *Fecula*, may be separated from a variety of vegetable substances; it is contained in the esculent *grains* and other *seeds*, in many *roots*, in the *stems* of several species of *palms*, (seldom in those of dicotyledonous plants,) and in different *lichens*. The process for obtaining it consists in diffusing the powdered or bruised grain or seed, or the rasped root or stem, in cold water, which becomes white and turbid; the grosser parts may be separated by a strainer, and the milky liquor which passes, deposits the starch, which is to be washed in cold water, and dried in a gentle heat.

COMMON STARCH may be obtained by steeping the grain containing it in water till it becomes soft; then putting it into coarse linen bags, and pressing them in vats of water: a milky juice exudes, and the starch falls to the bottom of the vat. The supernatant liquor undergoes a slight fermentation, and a portion of alcohol and acetic acid is formed, which dissolves some impurities in the deposited starch; it is then collected, washed, and dried in a moderate heat. The greater part of the starch employed in this country, is made in or near London. It may be obtained from the meal or flour of wheat, rye, or other grain, or from potatoes*, and other farinaceous roots, but the starch commonly sold is almost exclusively made from *wheat-meal*. The process consists in disengaging the fecula and other parts of the grain from the gluten, by fermentation and repeated washing. The wheat, coarsely ground, is put into a vat with a sufficient quantity of cold water, in which it lies and ferments, sometimes seven or eight days, and at others longer, according as it may be wanted, or as the weather promotes or retards fermentation. When the fermentation is over, which is known by the starch settling at the bottom of the vat, the whole is taken out by small quantities at a time, and put into hair-sieves and washed with water, which separates the bran from it, the fine parts running through the sieve with the water into shallow tubs, or vessels, called *frames*. The fermentation becomes acetous, and what runs through the sieves contains the starch suspended in a very foul acid liquor, called *sour water*. In about two days after this operation, the starch settles at the bottom of the frames, the sour water is then drawn off, and the dirty discoloured part, which is the last that subsides, and therefore is at the top, is scraped off; the surface of the remaining starch is then washed, till it is nearly free from the mucilaginous sediment. The top, called *slimes*, is put into another frame or tub, and treated similarly, to obtain the starch from it. The starch is stirred with fresh water and strained through a finer sieve into another frame or tub, when, being nearly cleansed of its impurities, it is called a *green water*. In two or three days the starch settles at the bottom of the frame or tub, where it is kept till it is either washed again, or *boxed*. If it is washed again, in the manner above described, the part washed off is called a *white water*, instead of a *slime;* the other part being still called a *green water*. The starch, being sufficiently pure and settled, is taken out of the frames or tubs, and put into oblong boxes, about five feet long and one broad, with holes in the bottom and lined with linen cloth, to drain and harden, where it soon becomes solid enough to be cut into square lumps: it is then turned out of the boxes and laid upon bricks (which absorb the moisture,) for two or three days to dry. When sufficiently hard, the pieces are put into the *stove*, a square building fitted up with racks, on every side, at proper distances for receiving the pieces, and heated from below. Here they remain in a moderate heat for about two days, till a slimy crust forms on the surface. When taken out of the stove, the crusted part is carefully scraped off, and the remainder, which is now perfect starch, is papered, labelled, and stamped, and placed again in the stove, with a good fire, for about three days, till quite dry. During this drying the lumps crack pretty uniformly into the small pieces, in which they appear when sold. The slimes and white waters are treated in the same way, till all the starch is got from them, and boxed, drained, and dried, as before. (See the *Eighth Report of the Commission of Excise Inquiry*, 1834.)

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* *Potato starch* is obtained by reducing potato to a pulp, and washing it with cold water upon a sieve; the fecula is deposited in the form of a white powder, denser than common starch, and exhibiting larger spherules under the microscope, but possessed of its essential characters. According to Dr. Pearson (*Repertory of Arts*, iii., 383), 100 parts of fresh potato, deprived of skin, contain water 68 to 72, and meal 32 to 28. The meal consists of starch 15 to 17, fibrous matter 8 to 9, mucilage 5 to 6.

Lampadius has also analyzed several varieties of the potato. (*An. of Phil.* v. 39.)

Sago, *Tapioca*, and *Cassava*, are also varieties of starch. *Sago* is produced, not from the *Cycas circinalis*, nor indeed from any species of *Cycas*, but from true palms of the genus *Sagus*, and of at least two species, the *Sagus genuina* (Rumphius), and *Sagus farinifera* (Lamarck.) See Hooker and Hamilton, in Curtis's *Botanical Magazine*, vol. lv., or *N. S*, vol. ii., Plates 2826, 2827.

The *pith* of these palms is mixed with cold water, and the starchy deposit granulated and dried: its colour depends upon the heat at which it has been desiccated. Though Sago possesses the leading character of starch, that of precipitating iodine blue, it differs from common starch by its solubility in cold water. (CAVENTOU.)

Tapioca and *Cassava* are prepared from an American plant, the *Iatropha manihot*, the milky juice of which is poisonous, but diffused through water deposits a harmless starch, nearly allied to sago.

Pure starch, from whatever source it is obtained, is a white substance, of a specific gravity about 1.5, insoluble in cold water, but readily soluble* at a temperature between 160° and 180°. Its solution is gelatinous, and by careful evaporation yields a substance resembling gum in appearance, which is a compound of starch and water. Starch is insoluble in alcohol and in ether, and occasions no precipitate in the greater number of metallic solutions; in solution of subacetate of lead, however, it occasions a copious precipitate. The most characteristic property

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[*] I have used the term *solution* of starch, as applicable to the ordinary appearances that ensue, but Raspail has shown that the varieties of starch consist of small brilliant spherules, each of which has a coating less soluble than its interior; that heat bursts these, and lets out their contents, which consist of a gum-like substance (called by Biot, *dextrine?*) the term *amidine* has also been applied to it. The different varieties of starch may, it is said, be discriminated, by their microscopic characters. Berzelius says, that the action of hot water upon starch is not a true solution, but a swelling up or gelatinization of the starch, and that only a small portion is actually dissolved: but, in reference to the general chemical agencies of starch, it will not be necessary to enter into these distinctions.

of starch is that of forming a blue compound with iodine; it may be obtained by adding an aqueous solution of iodine to a dilute solution of starch. (See p. 341.) Starch absorbs chlorine, becoming semifluid, brown, and sour, and evolving carbonic and muriatic acid.

When a decoction of starch (it should be *pure* and free from gluten,) is kept, in or out of the contact of air, for six or eight weeks, water being occasionally added to prevent desiccation, and the temperature between 60° and 80°, a portion of sugar is gradually formed in it. (Saussure, *Ann. de Chim. et Phys.*, xi., 379.) The following table shows more explicitly the nature of these changes *.

	A.	B.	C.	D.	E.	F.
Sugar	37.00	47.4	49.7	35.4	30.4	1.00
Gum	10.00	23.0	9.7	17.5	17.2	0.36
Amidine	14.30	8.9	5.2	18.7	17.0	1.00
Starch	5.83	4.0	3.8	9.4	9.3	98.00
Ligneous starch	10.53	10.3	9.2	7.0	4.4	
Carbonaceous lignin	trace	trace	0.3	trace	0.2	
Soft resin	0.30			loss 6.0		
	77.96	93.6	77.9	94.0	78.5	100.36

A, is the composition of the residue of 100 parts of *wheat-starch* made into a paste with 1200 of water, and left in a covered but not air-tight saucer for two years; a gray, mouldy, inodorous, semifluid paste, not acid, remained, which, dried at 212°, yielded the above results. B is a similar experiment, in which the starch-paste was kept for thirty-eight days, in a well-corked phial containing a little air. C the same as B, but air freely admitted. D, a similar paste of *potato-starch*, left for forty-two days in a bottle, with a tube cemented into it for carrying off gas; a little hydrogen and carbonic acid were evolved. E the same as D, but freely exposed. F, the starch-paste as above, left for forty days in a glass vessel filled with carbonic acid. The term *amidine*, in the above table, is applied "to a substance intermediate between gum and starch;" and *ligneous starch* to a product insoluble in boiling water and in many acids, but still becoming purple with iodine. The *carbonaceous lignin* gives a brown colour to the respective solutions. The influence of carbonic acid in preventing the decomposition of starch is strikingly shown by the contents of the last column. If *gluten* be present, starch begins to pass into sugar in a few hours †.

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* The facility with which sugar is sometimes formed is shown in the change which the pulp of many apples undergoes when exposed to air, becoming brown, and at the same time much sweeter. This character belongs to the apples which are preferred for *cyder*, and is obvious by the rapid alteration of colour which they exhibit when cut through so as to expose the interior.

† The change of starch into sugar is always observed during the *germination* of seeds, and in the process of *malting* a similar conversion is effected. (See page 870.)

Malt is barley which has been made to germinate to a certain extent, after which the process is stopped by heat. The barley is steeped in cold water, and is then made into a heap, or *couch*, upon the malt-floor: here it absorbs oxygen, and evolves carbonic acid; its temperature augments, and then it is occasionally turned, to prevent its becoming too warm. In this process the *radicle* lengthens, and the *plume*, called by the maltsters *acrospire*, elongates; and when it has nearly reached the opposite extremity of the seed, its further growth is arrested by drying at a temperature

The dilute acids dissolve starch, and the solution, by continued boiling, yields gum and sugar. The conversion of starch into sugar by these means was discovered by Kirchoff, of Petersburgh, not accidentally, but in consequence of Napoleon's exclusion of colonial produce from Russia, during the enforcement of what was termed the *Continental System:* his ingenuity was rewarded by the Emperor of Russia, with an annuity of 1000 rubles. His method consisted in boiling with very dilute sulphuric acid. A pound of starch may be digested in six or eight pints of distilled water, rendered slightly acid by two or three drachms of sulphuric acid. The mixture should be simmered for a few days, fresh portions of water being occasionally added to compensate for the loss by evaporation. After this process, the acid is saturated by a proper proportion of chalk, and the mixture filtered and evaporated to the consistence of syrup; its taste is sweet, and, by purification in the usual way, it affords *granular* sugar. Dr. Tuthill digested a pound and a half of *potato starch* (obtained from about 9 pounds of potatoes) in a mixture of 6 pints of distilled water, and a quarter of an ounce (by weight) of sulphuric acid, at a boiling-heat; the mixture was afterwards stirred, and fresh water occasionally added to supply loss by evaporation. After thirty-four hours an ounce of powdered charcoal was added, and the boiling resumed for two hours. The acid was then carefully saturated by lime, and the boiling continued for half an hour, when the liquor was strained through calico. The insoluble residue, after having been washed and dried, consisted of charcoal and sulphate of lime. The filtered liquor was evaporated to the thickness of syrup; and being set aside, became, in eight days, a crystallized mass, resembling brown sugar and treacle. The sugar weighed one pound and a quarter. One pound of it, fermented in the usual way, afforded, on distillation, 14 drachms of proof-spirit. (*Nicholson's Journal*, xxxiii.) MM. de la Rive and Saussure have shown that the contact of air is unnecessary in the above process; that no part of the acid is decomposed, no gas evolved, and that the actual sugar obtained exceeds, by about one-tenth, the original weight of the starch. Hence Saussure con-

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slowly elevated to 150° or more. The malt is then cleansed of the rootlets. According to Dr. Thomson, barley loses about 8 *per cent.* by converting it into malt, of which

1.5	is carried off by the steep-water.
3.0	dissipated on the floor,
3.0	roots separating by cleansing,
0.5	waste.
8.0	

The following are his comparative analyses of unmalted and malted barley, showing the changes which have taken place in the operation.

Gum	5	14
Sugar	4	16
Gluten	3	1
Starch	88	69
	100 barley	100 malt.

According to Proust (*Ann. de Chim. et Phys.*, v., 337), barley also contains a peculiar substance, insoluble in hot water, which he calls *hordein*, and which, during malting, is diminished in quantity, and converted into sugar or starch. Hitherto *hordein* appears to have been confounded with starch. The following are his comparative analyses:—

	In 100 of Barley.	In 100 of Malt.
Resin	1	1
Gum	4	15
Sugar	5	15
Gluten	3	1
Starch	32	56
Hordein	55	12
	100	100

The *starch* of malt also differs in some of its properties from that of barley.

cludes that the conversion of starch into sugar depends upon the solidification of water, a conclusion borne out by the comparative analyses. According to Kirchoff, nitric, muriatic, and oxalic acids may be substituted in the above process for sulphuric; but phosphoric, tartaric, and acetic acids, are ineffective. The actual nature, however, of the change is not satisfactorily understood, and the experiments showing that starch passes into sugar without the intervention of any acid whatever, render these results doubtful. I shall afterwards have occasion to notice an analogous conversion of wood into gum-sugar.

A true crystallizable compound of starch and sulphuric acid may be obtained by dissolving, in a gentle heat, one part of starch in three of sulphuric acid, previously diluted with thirty-six parts of water, and mixing the solution with alcohol, which throws down a precipitate composed of starch and *sulphate of starch;* when washed with alcohol, dissolved in a small portion of water, and left to spontaneous evaporation, acicular crystals of sulphate of starch are formed, from which the free acid, contained in the mother-liquor, may be washed with alcohol. These crystals are not perfectly soluble in water without slight decomposition. (Saussure.)

Concentrated sulphuric acid converts starch into a black magma, with the evolution of sulphurous acid: when water is added, more or less carbon is thrown down. Nitric acid easily dissolves starch when warm, and converts it into malic and oxalic acids, without a trace of mucic acid. Muriatic acid forms with starch a solution, which, if evaporated, becomes thick and brown. (Berzelius.)

With the fixed alkalis starch forms more decided compounds than with the acids. With caustic potassa it produces a combination soluble in water and in alcohol, from which acids separate the starch. Potato-starch is more readily dissolved by the alkalis than wheat-starch. Lime and baryta form with starch insoluble compounds, which fall when a solution of starch is added to lime or baryta-water. When a boiling solution of starch is mixed with subacetate or subnitrate of lead, a white curdy compound falls, and the subsalt becomes neutral. The precipitate consists, according to Berzelius, of 72 starch + 28 oxide of lead. None of the combinations of starch with the salts are interesting or important. It exerts, however, according to Vauquelin, an evident solvent power over phosphate of lime. According to Rose, the presence of starch prevents the precipitation of oxide of iron by the alkalis.

Starch combines with tannin, and the compound is best obtained by filtering a hot solution of starch in infusion of galls; as it cools, the *tannate of starch* falls. It is thrown down when a strong infusion of galls is mixed with one of starch, but the precipitate dissolves on the application of heat. Starch is not thus precipitated by all the varieties of tannin, nor does it apparently combine with artificial tannin.

When starch is heated to 212°, it loses a little in weight from the loss of water, not combined, but adhering, for starch is *anhydrous.* At a somewhat higher temperature it becomes pale-brown, modified in solubility, acquires a slight odour, and is converted into the *amidin* of some chemists. When heated till vapour rises from it, and it acquires a decided brown tinge, it is converted into a modification of gum, becoming soluble in cold and hot water, and losing its gelatinous character. Instead of blue, iodine gives it a dingy purple tint. Starch thus altered by roasting, is known in commerce under the name of *British gum*, and is often used as a substitute for gum arabic, in the processes of calico-printing, and for stiffening different goods. According to F. Marcet the ultimate components of *torrefied starch* are carbon 35.7, hydrogen 6.2, oxygen 58.1.

THE ULTIMATE ANALYSIS OF STARCH, regarding it as a compound of carbon and the elements of water, $(car + q,)$ has been variously represented in reference to its proximate equivalents, and till this is more accurately determined, the probable composition of the atom of starch must remain doubtful. If the *amylate of lead* be regarded as a compound of 3 atoms of starch and 1 atom of oxide of lead, the number 96 will be the equivalent of starch, and it will consist of

				Gay-Lussac and Thenard.	Prout.	Berzelius.
Carbon	7	42	43.75	43.55	42.80	44.250
Hydrogen	6	6	6.25	6.77	6.35	6.674
Oxygen	6	48	50.00	49.68	50.85	49.076
	1	96	100.00	100.00	100.00	100.009

The following, in other terms, are the comparative results of the ultimate analysis of three varieties of starch, dried at 212°*.

	Wheat Starch.	Arrow-root.	Potato Starch.
Carbon	42.80	44.40	44.25
Water	57.20	55.60	55.75
	100.00	100.00	100.00

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* Dr. Prout, referring to the identity in composition between the *sugar* of honey and arrow-root under the ordinary circumstances of the atmosphere, infers that differences exist among the varieties of *amylaceous principles* analogous to those existing among sugars; or, in other words, that there are *low* starches as well as *low* sugars; wheat-starch he places at the head of the starches, and considers arrow-root as the lowest variety. "Whether arrow-root," he observes, "be the lowest that exists, I am unable to say; but I have met with none lower; and have reason to believe that the greater portion of the other varieties of the amylaceous principle known to exist, like the varieties of sugar above given, are intermediate in their composition between arrow-root and wheat-starch.

"The identity of composition between wheat-starch and cane-sugar, and between the sugar of honey and arrow-root, seems to show that, though these bodies are not actually capable of assuming the crystalline form, yet the original tendency among their essential elements to combine in certain proportions (and perhaps to assume certain forms) still continues to operate, though in a mitigated degree, and thus to exert, as it were, a feeble *nisus*, or endeavour toward the maintenance of certain definite modes of existence."

In reference to what are usually called the *extraneous* or foreign ingredients of certain vegetable principles, Dr. Prout has the following remarks:—

"It has been known from the very infancy of chemistry, that all organized bodies, besides the elements of which they are essentially composed, contain minute quantities of different foreign bodies, such as the earthy and alkaline salts, iron, &c. These have been usually considered as mere mechanical mixtures accidentally present; but I can by no means subscribe to this opinion. Indeed, much attention to this subject for many years past, has satisfied me that they perform the most important functions: in short, that organization cannot take place without them. This point will be more fully investigated hereafter: at present it is sufficient merely to observe, that many of those remarkable changes which crystallized bodies undergo on becoming organized, are more apparent

Inulin. This modification of starch was discovered in 1804, by V. Rose, in the root of the *Inula helenium:* it has been found by Payen (*Ann. de Chim. et Phys.*, xxvi. 102,) in the tubers of the Dahlia, and also in other plants, so that a variety of names have been given to it in reference to its sources, such as *Dahline*, *Menyanthine*, *Datiscin*, &c. Rose obtained it in the form of a white precipitate, deposited during the cooling of a strong decoction of elecampane root. Payen procured it from the grated root of the Dahlia, which was first washed with cold water, then boiled with the addition of a little chalk, strained, and filtered through charcoal, and clarified by white of egg: it was then evaporated till a pellicle formed upon the surface: during cooling the inulin was deposited, to the amount of 10 *per cent.* of the original root. The expressed juice of the potato also yields a little inulin (about 3 *per cent.*) when evaporated.

Inulin is purified by dissolving it in hot water, and cooling the solution, when it is deposited in the form of a white insipid, inodorous, crystalline powder, specific gravity 1.356. Heated a little above 212°, it loses water and fuses. Iodine renders it yellow. It is insoluble in cold, but sparingly soluble in boiling alcohol: dilute acids dissolve it, and readily convert it, by boiling, into gum and sugar. In other respects also, it is analogous to common starch.

Lichen Starch; Lichenin. Most lichens contain a species of starch: it may be obtained from the *Lichen islandicus* as follows:—it is cut into shreds, and infused in about 18 parts of cold water, to which carbonate of potassa is added in the proportion of 120 grains to each pound of moss. After 24 hours the moss is drained upon a sieve, (not *pressed*,) and thoroughly edulcorated by cold water: it is then boiled in 9 pints of water down to 6, and the decoction strained and squeezed out whilst hot. The strained liquor, at first clear and colourless, becomes, on cooling, a gray opaque jelly, which, if suspended in a cloth, or dried on blotting-paper, becomes hard as it dries, and of a dark colour. Redissolved in boiling water, it may be again gelatinized. It is tasteless, insoluble in alcohol and ether, contains no nitrogen, and yields on destructive distillation the same products as potato-starch. It is only slightly soluble in cold water, and when long and repeatedly boiled, it loses its property of gelatinizing. Iodine renders it dingy green. The dilute acids prevent its gelatinization, and gradually change it into gum and sugar. It is copiously precipitated by subacetate of lead, but, in other respects, resembles common starch.

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than real; that is to say, their chemical composition frequently remains essentially the same; and the only point of difference that can be traced, is the presence of a little more or less of water, or the intimate mixture of a minute portion of some foreign fixed body. There is no term at present employed which expresses this condition of bodies, and hence, to avoid circumlocution, I have provisionally adopted the term *merorganized*, (*μέρος*, *pars* vel *partim*,) meaning to imply by it, that bodies on passing into this state become partly, or, to a certain extent, organized. Thus starch I consider as *merorganized* sugar, the two substances having, as we shall see presently, the same essential composition, but the starch differing from the sugar by containing minute portions of other matters, which, we may presume, prevent its constituent particles from arranging themselves in the crystalline form, and thus cause it to assume totally different sensible properties."

Uses of Starch. Wheat-starch is employed for stiffening various fabrics, and articles of wearing apparel*. In applying it to muslin, the addition of borax or of phosphate of soda or ammonia, would at the same time render it so far incombustible, as to prevent burning with flame, and obviate the accidents that so frequently ensue from that cause. A little smalt, prussian-blue, or indigo, is generally added to starch to cover its yellowish hue, and to render it more effective in overcoming the tinge that linen and cotton acquire when long worn. In this country, the consumption of starch, though considerable, is trifling compared with that in Holland and some other parts of the continent of Europe, where stiffly-starched caps and gauzes are much worn by the lower orders: since the abolition of the absurd custom of powdering the hair, there has also been a great falling off in the demand for starch.

Lozenges, and various articles of confectionary, consist partly of starch; and the sugar-plums, sold in the streets, are composed of the refuse parts of the starch mentioned in describing its manufacture, with chalk, gypsum, and other trash: a spurious *refined liquorice*, is also made upon the same principle. *Stone-blue*, is a compound of indigo or prussian-blue, and the inferior kinds of starch. Among the substances used to adulterate starch, porcelain-clay was at one time prevalent. Considered as an article of food, as a part of the diet of children and of invalids, and as a component of our most nutritious vegetables, starch is very important, and several of its varieties, are often resorted to medicinally. But although eminently adapted to form part of our food, it is not fitted for exclusive nutriment; and this would appear to be the case with all those proximate principles of vegetables which are deficient in nitrogen.

§ VI. Gluten and Albumen.

Many plants contain a principle which resembles animal matter, and to which the term *vegeto-animal* matter was formerly applied. Of this substance there are two leading varieties, which may be distinguished by the terms *gluten* and *albumen*.

Gluten, so termed from its adhesive character†, is found in many of the esculent seeds, and especially in *wheat*, associated with albumen and starch. Its characteristic properties are, insolubility in cold water, elasticity and adhesiveness when moist, solubility in boiling alcohol, and in

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[*] Potato-starch is said to be much more hygrometric than wheat-starch, and goods which are stiffened with it, are apt to give in damp weather, and to become mouldy if laid by.

[†] It is the presence of gluten in wheaten flour that renders it pre-eminently nutritious, and its viscidity or tenacity confers upon that species of flour its peculiar excellence for the manufacture of maccaroni, vermicelli, and similar pastes, which are made by a kind of wire-drawing, and for which the wheat of the South of Europe, (more abundant in gluten than our own,) is particularly adapted.

The superiority of wheaten over other bread depends upon the great tenacity of its *dough*, which, in *panary fermentation*, is puffed up by the evolved carbonic acid, and retained in its vesicular texture, so as to form a very *light* loaf.

some of the acids and alkalis: it is precipitated from some of its solutions by ferrocyanuret of potassium, and by infusion of galls.

When a thick paste of wheaten flour is tied up in a piece of coarse canvas, and washed and kneaded in water, till the whole of the starch is extricated, and the washings are no longer milky, it leaves a gray, viscid, adhesive, and elastic substance, which consists of gluten and albumen, with a little residue of starch. By boiling this substance in alcohol, it is separable into a soluble and insoluble portion; the soluble part is *gluten*,—the insoluble, *albumen*. *Gluten* is then obtained by mixing the alcoholic solution with water, and distilling off the alcohol: it separates in straw-coloured flocculi, which aggregate, on stirring them together, into an elastic mass, tasteless, and of a peculiar odour: exposed to air, it becomes superficially brown and glossy, and gradually dries into a semitransparent horn-like mass. If obtained by evaporating its alcoholic solution, it is yellow, brittle, and transparent. When moist gluten is digested in acetic acid, the greater part is dissolved, but a peculiar substance, particularly described by Berzelius (*Lehrbuch*), remains. When the acetic solution of gluten is evaporated, it leaves a colourless transparent residue; saturated by caustic or carbonated ammonia, a flocculent precipitate falls, having all the characters of the original gluten. When a solution of gluten in acetic acid, or in alkali, is mixed with sulphuric, nitric, or muriatic acid, the gluten separates apparently with its original characters, but, in fact, chemically combined with the precipitant acid. Neither acetic nor phosphoric acid precipitate gluten from its alkaline solution, and yet phosphoric acid has no especial solvent power on moist gluten. When the solution of gluten in caustic potassa is evaporated at a low temperature (below 110°), a white, opaque, and apparently neutral compound of gluten and potassa remains. Caustic ammonia has little solvent power over gluten in its ordinary viscid state, but an acid solution of gluten is not permanently precipitated by ammonia. The combinations of gluten with other bases are insoluble in water, and are precipitated when the solution of gluten in potassa is mixed with the earthy or metallic salts. The carbonated alkalis scarcely dissolve gluten, and when it is precipitated by them from its acid solutions, they do not redissolve the precipitate. The alkaline and acid solutions of gluten, give a white precipitate with corrosive sublimate; and when viscid gluten is put into a solution of corrosive sublimate, it shrinks, hardens, and loses all tendency to putrefy. An acetic solution of gluten is not affected by acetate or subacetate of lead, or by sulphate of iron, but is abundantly precipitated by infusion of galls.

Albumen is the portion of the original glutinous residue of wheat-flour, which is insoluble in alcohol; it remains in the form of a gray substance after the extraction of the gluten; it is easily dried, and becomes brittle and pulverulent. Taddei called this insoluble part of the viscid gluten of wheat, *Zimoma*, (from ζυμη, leaven or ferment); and the soluble portion, which we have above described as *gluten*, he called *Gliadine* (from γλια, glue.) When this form of vegetable albumen is subjected to the action of weak caustic potassa, it swells, softens and dissolves: this solution, like that of animal albumen, gives precipitates with most of the earthy and metallic salts, and is not permanently precipitated by phosphoric or acetic acids, but the stronger acids coagulate it. When vegetable albumen has been dried, it is no longer soluble in acetic and phosphoric acids, but swells up and becomes transparent, and if then boiled in water, it increases in bulk and loses its yellow tint, but is not dissolved. Veg-albumen is insoluble in carbonated alkalis; it is precipitated from its solutions by carbonate of ammonia, by ferrocyanuret of potassium, and by tincture of galls. Corrosive sublimate throws it down, when there is no excess of acid present.

Kirchoff and Saussure have made us acquainted with the remarkable action which gluten exerts upon starch. Two parts of starch are mixed with 4 of cold water, and gradually added to 20 parts of boiling water; a thick paste is formed, to which 1 part of finely-powdered gluten is added, and the mixture kept six or eight hours in a temperature between 120° and 170°; under these circumstances it becomes thin, clear, and sweet; part of the starch is converted into gum and sugar, a little carbonic acid is evolved, but no oxygen absorbed, and on evaporating to dryness, the residue amounts to the joint weight of the starch and gluten employed.

Kirchoff has shown that a small quantity of gluten is capable of thus saccharizing a large quantity of starch, and has pointed out the application of this fact to the production of sugar in *worts* and *wash*, and the consequent formation of alcohol when such liquors are fermented.

Gluten is a constituent of barley and rye; and a modification of it, under the name of *legumine*, is found in pease and beans. (See Einhof, Berzelius, and Braconnot, *Ann. de Chim. et Phys.*, xxxiv., 68.) The gluten of barley is an important agent in the change which that grain suffers in conversion into *malt*, and the action of ground malt upon viscid starch is analogous to that of gluten. Payen terms the saccharizing principle of malt or barley, *diastase*, and regards it as the agent by which starch is converted into sugar during the germination of seeds, and the expansion of buds.

All seeds which form an emulsion with water, contain a principle analogous to, if not identical with, albumen: it has sometimes been termed *emulsin*. In almond-emulsion this substance is mixed with oil; it may be separated by boiling, by which it is coagulated, and the adherent oil may be abstracted either by ether, or by absolute alcohol: the residue is *emulsin*. (*Amygdaline* of Döbereiner, *Albumino-caseum* of Payen and O. Henry.)

The *milk of the cow-tree*, which flourishes in the mountainous regions of Quito in America, and, according to Boussingault and Mariano de Rivero, closely resembles cows' milk in taste and appearance; and the milk of the *Carica Papaya*, examined by Vauquelin, contain peculiar modifications of gluten; and the same substances may be extracted from other *milky juices* of plants, instances of which will afterwards be adduced.

Yeast, which separates from *must* and *wort* during fermentation, has many of the properties of gluten.

All the substances which have been mentioned in this section are so far analogous, that their aqueous solutions undergo, under favourable circumstances, changes resembling those of putrefying animal matter. The plants which bear *cruciform flowers*, also contain a similar principle, and hence the offensive stench that arises from them whilst rotting in heaps, and their efficacy as *manures:* it is apparently the presence of *nitrogen*, as one of the ultimate elements of these plants, that gives them their peculiarities, and tends to the production of ammonia during their decomposition; but the whole of this subject has been as yet only imperfectly investigated. *Gluten* has been subjected to ultimate analysis with the following results.

	F. Marcet.	Zenneck.
Carbon	55.7	45.80
Hydrogen	7.8	3.37
Oxygen	22.0	30.33
Nitrogen	14.5	20.50
	100.0	100.00

Pollenin. The pollen of flowers contains a peculiar vegeto-animal principle, which was first distinguished by Fourcroy and Vauquelin in their examination of the pollen of the *date-tree*, and afterwards by John in his analysis of the seeds of the *lycopodium*, and of the pollen of the *tulip.* It is insoluble in water, alcohol, ether, oils, and alkalis, and highly inflammable, so that when thrown into a flame it burns with a kind of deflagration; hence lycopodium is used to produce theatrical lightning, being much cleaner and more brilliant and rapid in its combustion than resin. When pollen is digested in caustic potassa, it exhales ammonia, and when subjected to destructive distillation, ammonia is one of the products.

§ VII. Lignin.

This term is aptly applied to *woody fibre*, as it exists in the ligneous parts of trees and plants; but as with other proximate principles, there are several modifications of it, and although in its ordinary state it appears to be indigestible, it is easily modified by heat and other agents so as to be converted into gum and sugar; and in a highly-attenuated state of organization it forms an esculent, and probably nutritive part of many fruits and vegetables. As constituting the bulk of different woods, and as forming vegetable fibre, its applications in the arts of life are highly interesting and useful, its chemical properties therefore acquire a proportionate degree of importance.

The term *lignin* is generally applied to the fibrous residue which remains after the different principles already enumerated, and others, afterwards to be described, are extracted by various solvents; hence *insolubility* in water, in alcohol, and in dilute acids and alkalis is one of its more obvious characters. It is also recognised as the most durable product of vegetation, and the extreme perfection in which it is occasionally found in mummy-cases, in ancient buildings, as in the piles of bridges, and even in submerged forests, shows its power of resisting decay. When, however, it is long exposed to the joint energies of air and moisture, it often becomes pulverulent, acquiring a brown or gray colour, as we see in the rotten wood of very old trees. It is also liable to more rapid decay and disintegration under the influence, probably, of parasitic plants, especially where the place is damp, and air imperfectly admitted, as in cases of what is termed *Dry-rot.*

The density, and other mechanical properties of wood, are very various; its texture is porous and vascular, and what is usually termed *fibrous*, so that it splits more easily in one direction than in another. In its ordinary state, exclusive of lignin, it contains various soluble and other matters, which confer upon it various characters, as to colour, smell, taste, and uses, and the proportion of these varies in the same tree at different seasons, and at various periods of its growth. The recent wood of trees loses by drying, and by the action of ordinary solvents, from 1 to 10 *per cent.* About 95 *per cent.* of *lignin* is the average produce of the common woods. The apparent low specific gravity of wood is referable to its porosity, the density of lignin, or of wood free from air, varying, apparently, from 1.4 to 1.58. There are a few of the heaviest woods, such as box, guaiacum, and ebony, which are, in their ordinary states, denser than water.

Chlorine gradually bleaches lignin, and the varieties of wood and woody fibre may in this way be rendered perfectly white, as in the process for bleaching linen and cotton, in which, by the alternate action of weak acids and alkalis, and exposure to light, air, and moisture, or by the occasional employment of chlorine or its compounds, the colouring-matters are gradually abstracted or decomposed. Concentrated sulphuric acid gradually converts wood into a modification of gum, care being taken to keep it cold; and when diluted and boiled, sugar is formed, as observed in regard to starch, so that linen rags may be thus converted into sugar*. When sawdust and sulphuric acid are heated together, a black magma is produced, which, on dilution with water, deposits between 40 and 50 *per cent.* of carbonaceous residue. Nitric acid tinges wood yellow, and gradually disintegrates and decomposes it, producing oxalic acid. Paper, which is merely another form of lignin, is gelatinized by cold sulphuric acid: cold nitric acid converts it also into a gelatinous pulp, which is sometimes partially blued by iodine, and therefore appears to contain starch. Muriatic acid renders wood brown and black, but does not dissolve or decompose it. The weak alkaline solutions exert scarcely any action on wood; but when heated with caustic potassa it is changed into a brown soluble matter, which appears to contain a peculiar extractive matter, like ulmin, and acetic acid. Wood combines with some of the salts, and others it decomposes. It combines with alumina, when steeped in solutions of alum or acetate of alumina; and when digested in solution of corrosive sublimate, a compound results, which resists decay, under circumstances tending to rot unprepared wood. Sulphate of copper, sulphate of iron, and several other salts, appear capable of forming analogous combinations. It is upon these attractions of woody fibre that the art of dyeing and of calico-printing mainly depend, for linen and cotton are, as I have already observed, mere modifications of lignin: paper also is made of linen or cotton rags; and hay, straw, leaves, and shavings of wood may, by proper means, be reduced to a pulp capable of being formed into paper.

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* We are indebted to M. Braconnot for some highly-interesting experiments, relating to the action of sulphuric acid on wood. (*Ann. de Chim. et Phys.*, xii., 172.) In the course of these researches, he triturated 25 parts of hempen cloth with 34 of the acid: it acquired the consistency of mucilage, which, after 24 hours, was almost entirely soluble in water. The diluted liquor was saturated with chalk, filtered, and evaporated to the consistency of syrup; it deposited sulphate of lime, and was then further evaporated to dryness, when a substance, having the characters of gum, was obtained. In another experiment, 24 parts of lignin were reduced to gum by 34 of sulphuric acid; this acid mixture, diluted with water, and boiled for 10 hours, became sweet; the acid was then separated by chalk, and the liquor, on due evaporation, afforded a crystallizable sugar.

The action of heat upon wood, under different circumstances, is extremely interesting, as the following outline of this part of its history shows. When wood is thoroughly dried at a temperature of about 220° it shrinks and splits, or if in powder loses variably in weight, depending upon its humidity: it again absorbs moisture from the air. When wood is carefully baked, so as to become of a pale-brown colour, it acquires solubility in water to some extent, yielding a brown infusion, which, when carefully prepared, tastes and smells like *toast and water:* and, indeed, under proper management, it may be converted into a palatable and nutritious bread. Something of this kind is used by the peasantry of Norway and Sweden; and the following directions are given for the purpose by Professor Autenrieth of Tubingen: he employed *beech* and similar woods, destitute of turpentine. "In the first place, everything that was soluble in water was removed by frequent maceration and boiling. The wood was then reduced to a minute state of division, that is to say, not merely into fine fibres, but actual powder; and after being repeatedly subjected to the heat of an oven, was ground in the usual manner of corn. Wood thus prepared, according to the author, acquires the smell and taste of corn-flour. It is, however, never quite white, but always of a yellowish colour. It also agrees with corn-flour in this respect, that it does not ferment without the addition of leaven, and in this case sour leaven of corn-flour is found to answer best. With this it makes a perfectly uniform and spongy bread; and when it is thoroughly baked, and has much crust, it has a much better taste of bread than what in time of scarcity is prepared from the bran and husks of corn. Wood-flour also, boiled in water, forms a thick, tough, trembling jelly, like that of wheat-starch, and which is very nutritious." (Prout, *Phil. Trans.*, 1827.)

When wood is burned in the air, it affords large quantities of inflammable gases which produce flame and render it a valuable fuel; and if decomposed with a partial access of air only, it leaves common charcoal, the relative proportions of which, as afforded by the different kinds of wood, have already been noticed. Subjected to destructive distillation in close vessels, *water*, *empyreumatic oil* and *tar*, *pyroxylic spirit*, and *acetic acid*, together with gaseous compounds of carbon and oxygen, and carbon and hydrogen, are the results. These, and the various products into which they are resolvable, have lately attracted the attention of several chemists, and will require more detailed notice.

Ultimate Composition of Lignin. With regard to the ultimate elements of lignin, Gay Lussac and Thenard first rendered it probable that the hydrogen and oxygen in this principle exist in it in the proportions in which they form water. The variety of forms in which lignin occurs in different woods is so great as to render a separate examination of each of them impossible; Dr. Prout, therefore, selected *two* for the purpose of analysis, *viz.*, the woods of the *Box* and *Willow*, which appeared to present the greatest contrast; the one being among the densest, the other the lightest of the woods. These were both treated exactly in the same manner; that is to say, they were first reduced to the form of a coarse powder by rasping, then well pulverized in a Wedgwood mortar, and afterwards sifted. Being by these means reduced to the form of impalpable powders, they were boiled in repeated portions of distilled water, till that fluid came off unchanged. After this they were similarly treated with alcohol, and finally again with distilled water. They were now exposed to the atmosphere, when in a dry and favourable state; and when they ceased to lose weight were submitted to analysis, and found to consist of (abstracting foreign matters)

	Box.	Willow.
Carbon	42.7	42.6
Water	57.3	57.4
	100.0	100.0

A known weight of each was then exposed for twenty-four hours to a temperature of 212°, and afterwards for six hours longer (by means of an oil-bath) to a temperature between 300° and 350°; and at the end of this time they were found to have lost, *per cent.*,

Box.	Willow.
14.6	14.4

Analyzed in this state of desication, they were found to consist of

	Box.	Willow.
Carbon	50.0	49.8
Water	50.0	50.2
	100.0	100.0

showing that the loss of weight arose from the escape of water. These latter results nearly agree with those of MM. Gay Lussac and Thenard, as obtained from the analyses of the woods of the *Oak* and *Beech*, and seem to show, beyond a doubt, that the composition of all of them is similar, or that they consist of *equal weights of carbon and water;* to which simple analogy, Dr. Prout observes, this important principle probably owes its stability.

We have no satisfactory data from which the proximate atomic weight of wood can be inferred, so that assuming it at its lowest equivalent, it may be regarded as composed of

				Prout.	Gay Lussac and Thenard.
Carbon	3	18	50.00	49.80	51.45
Hydrogen	2	2	5.56	5.58	5.82
Oxygen	2	16	44.44	44.62	42.73
	1	36	100.00	100.00	100.00

The *Proximate Vegetable Principles* now examined constitute the principal *nutritive* ingredients in vegetable food, and with the exception of gluten and albumen, appear to be, in reference to ultimate composition, *hydrates of carbon.*

The following Table, drawn up by Sir H. Davy, exhibits the relative proportions of soluble matter contained in 1000 parts of the different vegetable substances enumerated in the first column (*Agricultural Chemistry*, 4to., p. 131):—The deficiency may be considered as water, and inert insoluble substances; and the soluble matters may be regarded as those upon which the nutritive powers of the different vegetables depend.

VEGETABLES or VEGETABLE SUBSTANCES.	Whole quantity of Soluble or Nutritive Matter	Mucilage or Starch.	Saccharine Matter or Sugar.	Gluten or Albumen.	Extract, or matter rendered insoluble during evaporation.
Middlesex Wheat, aver. crop	955	765	—	190	—
Spring Wheat	940	700	—	240	—
Mildewed Wheat of 1806 .	210	171	—	32	—
Blighted Wheat of 1804 . .	650	520	—	130	—
Thick-skinned Sicilian Wheat of 1810	955	725	—	230	—
Thin-skinned Sicilian Wheat of 1810	961	722	—	239	—
Wheat from Poland . . .	950	750	—	200	—
North American Wheat . .	955	730	—	225	—
Norfolk Barley	920	790	70	60	—
Oats from Scotland . . .	743	641	15	87	—
Rye from Yorkshire . .	792	645	38	109	—
Common Beans	570	426	—	103	41
Dry Pease	574	501	22	35	16
Potatoes	from 260 to 200	from 200 to 155	from 20 to 15	from 40 to 30	—
Linseed Cake	151	123	11	17	—
Red Beet	148	14	121	14	—
White Beet	136	13	119	4	—
Parsnep	99	9	90	—	—
Carrots	98	3	95	—	—
Common Turnips . . .	42	7	34	1	—
Swedish Turnips . . .	64	9	51	2	2
Cabbage	73	41	24	8	—
Broad-leaved Clover . .	39	31	3	2	3
Long-rooted Clover . . .	39	30	4	3	2
White Clover	32	29	1	3	5
Sainfoin	39	28	2	3	6
Lucerne	23	18	1	—	4
Meadow Fox-tail Grass . .	33	24	3	—	6
Perennial Rye Grass . .	39	26	4	—	5
Fertile Meadow Grass . .	78	65	6	—	7
Roughish Meadow Grass .	39	29	5	—	6
Crested Dog's-tail Grass . .	35	28	3	—	4
Spiked Fescue Grass . .	19	15	2	—	2
Sweet-scented Soft Grass .	82	72	4	—	6
Sweet-scented Vernal Grass .	50	43	4	—	3
Fiorin	54	46	5	1	2
Fiorin cut in Winter . .	76	64	8	1	3

§ VIII. Vegetable Extract.

Under the term *extract*, the pharmaceutical chemists originally included all substances capable of being extracted from vegetable products by decoction in water, and of being obtained in a solid form by evaporation. It of course contained all the preceding substances included in this chapter, and many others afterwards to be mentioned; its properties were therefore extremely various and indefinite. They afterwards endeavoured to distinguish its varieties by the terms bitter, sweet, mucilaginous, astringent, narcotic, colouring, and resinous extracts, &c.; but in general, any brown residue obtained by boiling down the decoctions, or infusions, or even the expressed juices of vegetables, was distinguished by the generic term *extract*. Boerhaave first pointed out the existence of a peculiar substance in these extracts, soluble both in alcohol and in water, which he called *Materia hermaphrodita*. Scheele called it *Materia saponacea;* and Vauquelin afterwards gave the name *extractive matter* to what he regarded as a peculiar vegetable principle, soluble in water and alcohol, insoluble in ether, and becoming insoluble in water by long-continued boiling, and by exposure to light and air.

It seems probable that the *brown extractive*, obtained by the above processes, is not pre-existent in the vegetables whence it is obtained, but principally a *product* of the action of heat, water, air, and other agents; the different colouring-matters of plants have also been termed *coloured extractive*, but these we shall consider separately*. It will also be found in regard to many of the pharmaceutical extracts, that their activity resides in some peculiar and distinct proximate product, mixed with other unimportant and inactive substances, and these must also be distinctly considered.

Ulmin. The term *extractive* is perhaps most appropriately applied, in a strict chemical sense, to the peculiar brown matter which may be extracted from bog-earth, peat, and turf; it is frequently termed *humus*, or *humine*, (*Moder* of the Germans, *Gëine* of Berzelius.) There is also a brown exudation found upon the barks of trees, and especially of the elm, and hence called *ulmin*, which contains a similar matter combined with potassa. Lastly, the action of heat, acids, alkalis, and some other chemical agents, upon a variety of organic products, is attended by the production of more or less of a similar matter. As it combines with bases, Boullay terms it *ulmic acid;* and according to him, the brown matter occasionally produced by the decomposition of hydrocyanic acid, contains it united with nitrogen; this he calls *azulmic acid* (*Ann. de Chim. et Phys.*, xliii., 273.) He represents ulmin, or ulmic acid, as a compound of

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* In preparing *extracts* for pharmaceutical use, the greatest care must be taken to avoid injuring them by heat, and they should accordingly be evaporated in a water-bath, or by steam not exceeding 212°. It is easy to evaporate at lower temperatures, as in vacuo, or even over sulphuric acid, and many of the extracts used in medicine may be so obtained, of much greater activity than when prepared in the usual way: but for medical use this is perhaps not desirable; *uniformity* is the great object, and whether half a grain or two grains of the more powerful extracts is a dose, is of less importance, than the certainty that they are as far as possible of a given power.

56.7 *per cent.* carbon, and 43.3 hydrogen and oxygen in the proportions to form water: he considers it as the most important ingredient in the soil as relates to its nutritive powers. Malaguti is quoted by Dumas (*Chim. App. aux Arts*, v., 399), as having obtained *crystallized ulmic acid* by the long-continued action of very dilute nitric acid upon sugar at a boiling heat.

Ulmin, or *ulmic acid*, may be obtained by digesting the brown exudation of the elm in boiling water, and precipitation by an acid. Rotten leaves, bog-earth, wood-soot, or turf, may be digested in a weak solution of caustic or carbonated potassa, by which a brown liquid is obtained (*ulmate of potassa*), from which acids throw down ulmin. Braconnot procures it (*Ann. de Chim. et Phys.*, xii., 192) by heating equal weights of caustic potassa and sawdust, or shavings of wood, with a little water, in a silver crucible, continually stirring the mixture: when it suddenly boils up, it is removed from the fire, and stirred till cold, so as to expose it as much as possible to the air, for the formation of ulmic acid in this case depends upon the absorption of oxygen. When cold, the product is dissolved in water, filtered, and decomposed by diluted sulphuric acid; the precipitated ulmic acid is then washed and dried.

Ulmic acid varies in appearance according to its state and source: when recently precipitated it is in brown flocks; but when dried, brittle and resin-like. It is nearly tasteless, almost insoluble in water, but communicates a brown tinge to it. Sulphuric acid dissolves it, but lets it fall on dilution, and it then retains a little acid: it combines and forms soluble compounds with the alkalis; with the alkaline earths, and many of the other oxides, it produces combinations which are insoluble or difficultly soluble; but the characters of these compounds, as given by different authorities, are much at variance. Some of the metallic salts precipitate it so completely as to leave the supernatant liquid colourless. Some of its compounds form useful pigments (*Umbers* are of this description ?) and may be employed in dyeing and calico-printing.

Bitter Extractive. Whether any peculiar organic product does or does not give rise to the bitter flavour of many of the pharmaceutical extracts, such as those of *quassia*, *wormwood*, *centaury*, and others, from which no distinct crystallizable substance has hitherto been obtained, or whether it is a property belonging to *extractive*, without conferring upon it any distinctive character beyond that of bitterness, are questions which still remain to be decided. The existence of the intensely bitter and definite compounds called *vegeto-alkalis*, leads to the suspicion of some analogous source of bitterness in other cases, but there are many plants in which these cannot be detected, and in which the bitterness seems to reside in a principle having the essential characters of *extractive*. The following are some of the most important of them.

Aloe-bitter. The substance known in commerce under the name of *aloes*, is the extract of several species of aloe, such as the *spicata*, *vulgaris*, &c. It is brown, sometimes translucent and sometimes opaque, and of a peculiar odour, especially when breathed upon: it is almost entirely soluble in water and in common alcohol; the portion insoluble in water has not the characters of a resin, but appears to be oxygenized extractive. When its aqueous solution is cautiously evaporated it leaves a brown residue soluble in water, but insoluble in ether and in anhydrous alcohol. Chlorine throws down from its aqueous solution a brown substance, resembling the original insoluble part. Sulphuric acid dissolves it without apparent change; cold nitric acid dissolves it and acquires a greenish tint, and when the solution is heated malic and oxalic acids are formed, and a red resinous substance, of an agreeable odour. When 1 part of aloes is dissolved in 8 of nitric acid, and evaporated to dryness, the residue is yellow and intensely bitter; it deflagrates when heated, and communicates a deep-purple tint to water, and to alkaline solutions. It forms yellow solutions in the acids, and is not precipitated by the salts which throw down unaltered extractive. (Braconnot, *Ann. de Chim. et Phys.*, lxviii., 24.)

From *rhubarb-root*, *squills*, *briony*, *gentian*, and several other drugs, bitter substances have been extracted, but none of them are possessed of sufficiently distinctive characters to enable us to consider them as *proximate bitter principles:* such as are most definite, or crystallizable, will be noticed in another section.

Artificial Bitter. By digesting indigo, silk, and a few other substances, both of vegetable and animal origin, in nitric acid, an intensely-bitter matter is formed, called by Welther the *yellow bitter principle.* (*Ann. de Chim.*, xxix.) Chevreul has rendered it probable that this is a compound of a peculiar product with nitric acid. It is crystallizable, burns like gunpowder, and detonates when struck with a hammer.

§ IX. ASTRINGENT EXTRACTIVE; TANNIN; TANNIC ACID; GALLIC ACID; ELLAGIC ACID; PYROGALLIC ACID; METAGALLIC ACID.

THERE are numerous vegetables which have more or less of an *astringent* flavour, and of which the aqueous decoctions or infusions occasion a precipitate in solutions of animal jelly, and in those of several metallic salts: they change the persalts of iron to dark blue, or dingy green. These well-marked properties have long been ascribed to a peculiar proximate principle, designated *tannin*, as being essential to the conversion of skin into leather: its power of combining with salifiable bases led some chemists to term it an *acid*, and it appeared in many cases to be associated with, and sometimes apparently a modification of, *gallic acid.* It has, however, been obtained in a distinct form by Pelouze, (*Ann. de Chim. et Phys.*, liv., 337,) and its characters are such that it may be appropriately termed *tannic acid.* But the properties of the vegetable infusions and decoctions containing *astringent matter*, are not solely referable to tannic acid, but appear to depend upon its association with extractive, and in some cases with gallic acid; hence the varied effects which they produce when tested by the above-mentioned reagents, and the division (adopted by some chemical authors) of astringents into two classes, namely, those producing *blue* or *black*, and those producing *green* precipitates with persulphate of iron.

The relative proportion of tannin, in different vegetables, may be tolerably-well judged of by the weight of the precipitate which they afford in a strong solution of isinglass. The following table, by Cadet, shows the relative weights of the precipitates formed by an infusion of 100 parts of the respective substances.

Galls	86	Weeping willow bark	16
Tormentil root	50	Bohemia olive bark	16
Alder bark	36	Bark of *coryaria myrtifolia*	13
Apricot bark	32	Bark of *rhus typhinum*	10
Pomegranate rind	32	Green acorn cups	10
Oak bark	25	Service-tree bark	8
Cherry-tree bark	24	Horse-chestnut bark	6
Bark of the *cornus mascula*	19	American sumach bark	6
Plane-tree bark	16		

In the following table, the first column shows the whole quantity of extract obtained from 100 parts of the different substances, and the second column the proportion of tannin in that extract. (Davy.)

	Extract	Tan contained in it.		Extract.	Tan contained in it.
Galls	37.5	26.4	Entire willow bark		2.2
Inner bark of oak	23.5	16.0	Sumach	34.3	16.2
—— horse-chestnut	18.5	15.2	Souchong tea	32.5	10.0
Entire oak bark	12.7	6.3	Green tea		8.5
—— horse-chestnut do.	11.0	4.3	Catechu from Bombay		54.3
—— elm bark		2.7	——— Bengal		48.1

The *average* quantity of tannin, in 480 lbs. of different barks, is as follows: (Davy, *Agricul. Chem.*)

	℔.		℔.
Entire bark of middle-sized Oak, cut in spring	29	Entire bark of Lombardy poplar	15
—— Spanish chestnut	21	—— Birch	8
—— Leicester willow, large size	33	—— Hazel	14
—— Elm	13	—— Black-thorn	16
—— Common willow, large	11	—— Coppice oak	32
—— Ash	16	—— Oak, cut in autumn	21
—— Beech	10	—— Larch, cut in autumn	8
—— Horse Chestnut	9	White interior cortical layers of oak-bark	72
—— Sycamore	11		

The infusions and decoctions of vegetables containing tannin, not only affect solutions of jelly and of peroxide of iron, as above stated, but they also precipitate the salts of lead, tin, copper, and indeed of most of the metals: these precipitates are of variable composition, and often contain extractive, and tannin, and gallic acid.

The following plants contain the modification of tannin which renders solutions of peroxide of iron *deep-blue*. (Gmelin.) *Galls;* the *roots* of *Lithrum salicaria*, *Geum urbanum* and *rivale*, *Potentilla argentea* and *anserina*, *Sanguisorba officinalis*, *Poterium sanguisorba*, *Alchemilla vulgaris*, *Arctium lappa*, *Polygonum bistorta*, *Iris pseudacorus*, *Nymphæa alba;* the *wood* of the oak, and many other trees; the *bark* of different species of oak; the *twigs* of the black currant and of sumach; the *leaves* of oak, *uva ursi*, and many others; the *petals* of pomegranate, *Rosa gallica*, and *Pæonia officinalis*.

The tannin which gives a *green* precipitate with persalts of iron, is found in catechu and in kino; in the roots of the *Tormentilla erecta*, *Potentilla reptans*, *Rosa canina*, *Rhæum rhaponticum*, &c.; in the different species of Cinchona bark, in cinnamon, cassia, and in horse-chestnut bark; in the leaves of *Salvia officinalis*, *Lamium album*, *Glecoma hederacea*, &c.; in the varieties of *tea;* in the *flowers* of *Tilia Europæa*, *Centaurea cyanus*, and *Arnica montana;* in horse-chestnuts, date-stones, &c.

Several processes have been suggested for the separation of *pure tannin* from the solutions in which it is combined with other vegetable principles; they generally consist in throwing it down in combination either with sulphuric acid, which is afterwards abstracted by carbonate of lead or carbonate of baryta; or by subacetate of lead, or chloride of tin, the tannates of lead or tin, which fall, being afterwards decomposed by sulphuretted hydrogen. In these cases, solutions of a more or less pure tannin are obtained, which are filtered through animal-charcoal, and cautiously evaporated. But tannin, as we shall presently find, is very prone to change, and the action of acids, bases, salts, and sulphuretted hydrogen, probably tend to modify it; hence the preference due to the following process, suggested by Pelouze, and which appears unexceptionable. The lower opening of an elongated glass vessel is loosely closed by a piece of linen, or a plug of tow, and it is then half filled with powdered galls gently pressed down: *common* ether (hydrous ether) is then poured in, and the upper orifice being closed so as to admit a little air, but prevent evaporation, it slowly filters through the galls into the vessel underneath, where it forms two distinct liquids; the one light and very fluid, the other more dense and slightly yellow; more ether is poured in above, till the lower stratum of liquid no longer is increased in quantity. The liquids are then poured into a funnel, the tube of which is at first stopped by the finger, and, when they have separated into two portions, the heaviest is drawn off into a capsule, and the lighter put aside for distillation, it being chiefly ether. The denser liquid is then purified by washing it with anhydrous ether, from which it is separated as before, and ultimately evaporated in a stove, or under the receiver of the air-pump; a spongy product is obtained, not crystalline, white, or with a slight yellow tint, and amounting to from 35 to 40 *per cent.* of the galls employed. It is tannin, as pure as it can be procured*.

Tannic Acid or Tannin, in this state, is eminently astringent, without any bitterness, inodorous, and, though very sparingly soluble in water, the solution reddens litmus. It decomposes the alkaline carbonates with effervescence, and forms insoluble precipitates in the greater number of metallic solutions, which are true *tannates*. The pure protosalts of iron are not altered by it, but in the persalts it occasions an abundant dark-blue precipitate. It is less soluble in anhydrous alcohol and ether than in water. It cannot be crystallized. It burns upon platinum-foil without

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* *Artificial Tannin.* Mr. Hatchett has shown that a species of tannin may be formed artificially by digesting charcoal in dilute nitric acid during several days; it is at length dissolved, and a reddish-brown liquor is obtained, which furnishes, by careful evaporation, a brown glossy substance, amounting to about 120 parts from 100 of charcoal.

This *artificial tannin* differs in one circumstance from natural tannin, which is, that it resists the action of nitric acid, by which all the varieties of natural tannin are decomposed, though some are more capable of resisting its action than others.

Artificial tannin has a bitterish astringent taste, is soluble in water and alcohol, residue. Its concentrated solution is precipitated *white* by muriatic nitric, sulphuric, phosphoric, and arsenic acids: it is not affected by tartaric, oxalic, lactic, citric, acetic, succinic, selenious, or sulphurous acids. Heated with nitric acid it is rapidly decomposed, and oxalic acid is formed. With cinchonia, quinia, morphia, codeia, brucia, and strychnia, it forms white precipitates, sparingly soluble in water, but very soluble in acetic acid.

The aqueous solution of tannic acid may be long preserved without change provided air be excluded, but in open vessels it absorbs oxygen, evolves carbonic acid, becomes turbid, and deposits *gallic acid*, into which, therefore, it is converted; this is the reason why recently-prepared infusion of galls precipitates several substances (in the form of tannates) which it will not throw down after long exposure to air, its tannin having then passed into gallic acid. This is especially the case with solutions of morphia, the tannate of which is insoluble, but the gallate, soluble.

Tannin forms a white precipitate in solution of gelatin (*tannogelatin*), which, when carefully dried, becomes hard and tough; if gelatine predominate, the precipitate may be redissolved by heat in the supernatant liquid; but if the tannin be in excess, the precipitate becomes elastic and agglutinated. Tannogelatin dried at 212° consists of about 54 tan, and 46 gelatin. Tannin cannot, in this way, be wholly separated from its solutions by a solution of gelatin, but when a piece of skin, previously cleansed and soaked in lime-water (as it is prepared for tanning) is used, it absorbs the whole of the tannic acid, leaving in solution any gallic acid that might have been present. Tannin precipitates albumen and vegetable gluten.

When gelatinous alumina is agitated with solution of tannin, it rapidly absorbs it, forming an insoluble precipitate, and the filtered liquor does not discolour persulphate of iron: this is not the case with gallic acid.

When tannin is subjected to the temperature of boiling-oil, water, carbonic acid, and metagallic acid are formed. Dried at 240° it is not decomposed, but becomes anhydrous. In this state it consists of*

				Berzelius.	Pelouze. *mean of 4 expts.*
Carbon	18	108	50.70	52.69	51.56
Hydrogen	9	9	4.23	3.86	4.20
Oxygen	12	96	45.07	43.45	44.24
	1	213	100.00	100.00	100.00

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and forms an insoluble precipitate in solutions of animal gelatine, the precipitate consisting, according to Mr. Hatchett, of

36 tannin
64 gelatine
100

Muriatic and sulphuric acids occasion brown precipitates, in solution of artificial tan, which are soluble in hot water. It combines with the alkalis, and forms a precipitate of difficult solubility in aqueous solutions of lime, baryta, and strontia, and most metallic solutions: these precipitates are of a brown colour.

A variety of artificial tan is formed by digesting camphor and resins in sulphuric acid, till the liquor becomes black, and on being poured into water, deposits a black powder, which, by digestion in alcohol, furnishes a brown matter, soluble in water, and forming an insoluble precipitate with gelatine. — Hatchett, *Phil. Trans.*, 1805, 1806.

* The tannin of catechu is said to contain less oxygen than that of galls: *tannous acid?*

but its equivalent deduced from the neutral tannates, is $213 \times 2 = 426$, so that our symbol tan' represents $(36\,car + 18\,h + 24\,o) = 426$.

Tannate of Potassa. When solution of tannic acid is added to a solution of caustic potassa or its carbonate, a precipitate falls, scarcely soluble in alcohol or water; it forms a gelatinous compound when hydrated, and when dry, assumes an earthy aspect.

Tannate of Soda is more soluble than tannate of potassa.

Tannates of Baryta, Strontia, and Lime, are difficultly soluble in water, but they dissolve in excess of tannic acid, and in acetic acid.

Tannate of Peroxide of Iron $(fe + 1\frac{1}{2}\,o + 1\frac{1}{2}\,tan')$; Pertannate of Iron. This salt corresponds in composition with the best defined salts of iron; it consists of 1 atom of *peroxide of iron*, and $1\frac{1}{2}$ of *tannic acid*. It is important, as constituting the basis of common *writing-ink**.

Tannate of Lead, $(pl + o) + (36\,car + 18\,h + 24\,o)$ or $(\mathrm{Pl} + tan')$ is formed by dropping a solution of nitrate or of acetate of lead into a solution of tannic acid, leaving the latter in excess. It is white and insoluble, and, if *neutral*, as it probably is, it consists of

				Berzelius.
Oxide of lead	1	112	34.2	34.21
Tannic acid	1	426	65.8	65.79
	1	538	100.0	100.00

Tannate of Antimony. The compound of tannic acid with protoxide of antimony is thrown down from a solution of emetic tartar, in the form of an insoluble white gelatinous precipitate.

General Characters of the Tannates. The salts of the tannic acid are mostly of difficult solubility; those which are soluble do not precipitate gelatin except an acid be added. With the white oxides the pure tannates are white; with the coloured oxides, variously coloured. Infusion of galls, or a solution of tannic acid, are often used as reagents, indicating by the colour of the produced precipitate, the nature of several of the oxides. The test should be applied to neutral solutions, for the effect is modified by the presence of free acids.

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* In making good *Writing Ink*, the great object is to regulate the proportion of sulphate of iron to the galls. If it be in excess, although the ink may at first appear black, it becomes subsequently brown and yellow. Hence, some time should elapse before ink is used after the ingredients are put together, in order to be tested from time to time, and the combinations perfectly regulated. Gum is added to retain the colouring matter in suspension, to prevent too great fluidity in the writing, and to protect the vegetable matter from decomposition. Logwood, and other vegetable astringents, have been tried for atramental purposes, but do not yield a permanent ink.

An excellent ink is obtained as follows; but, if the paper has been made from inferior rags, bleached by an excess of chlorine, ink, however good, will be ultimately discoloured.

Aleppo galls 6 oz., sulphate of iron 4 oz., gum-arabic 4 oz, water 6 pints. Boil the galls in the water, then add the other ingredients, and keep the whole in a wooden or glass vessel, occasionally shaken. In two months, strain, and pour off the ink into glass bottles, to be well corked. To prevent mould, add one grain of corrosive sublimate, or three drops of kréosote to each pint of ink. Sulphate of copper is occasionally added to ink, but is rather injurious than otherwise.

A *blue ink*, or *writing fluid*, has lately been introduced: I am not acquainted with its composition, but the colouring-matter is said to be sulphate of indigo and tannogallate of iron.

In the following Table of these precipitates by *infusion of galls*, the first column contains my own results, the second those given by Dumas:—

METAL.	SOLUTION.	PRECIPITATE.	
Manganese	Neutral protomuriate	Dirty yellow	0
Iron	Neutral protosulphate	Purple tint	0
Ditto	Persulphate	Black	Blue-black
Zinc	Chloride	Dirty yellow	0
Tin	Acid protochloride	Straw-colour	Yellowish
Ditto	Acid perchloride	Fawn-colour	Ditto
Cadmium	Chloride	?	0
Copper	Protochloride	Yellow-brown	?
Ditto	Nitrate	Green	Gray
Lead	Nitrate	Dingy yellow	White
Antimony	Tartrate of antimony and potassa	Straw-colour	White
Bismuth	Tartrate of bismuth and potassa	Yellow, and copious	Orange
Cobalt	Chloride	0	Yellow-white
Uranium	Sulphate	Dark brown	Reddish-brown
Titanium	Acid muriate	Brown-red	Blood-red
Ditto	Neutral sulphate	Blood-red	Ditto
Cerium	Sulphate	Yellowish	Yellow
Tellurium	Chloride	Yellow	Yellow
Arsenic	White oxide	Little change	?
Ditto	Arsenic acid	0	?
Molybdenum	Chloride	Brown	Brown
Nickel	Sulphate	Green	Yellow-green
Mercury	Acid protonitrate	Yellow	?
Ditto	Acid pernitrate	Yellow	?
Ditto	Corrosive sublimate	0	?
Osmium	Aqueous solution of oxide	Purple becoming blue	Blueish-purple
Rhodium			
Palladium			
Silver	Nitrate	Curdy and brown	Dirty-yellow
Gold	Chloride	Deep brown	Brown
Platinum	Chloride	Brownish-green	Dark-green

Gallic Acid. The researches of Pelouze have thrown much light on the nature and production of *gallic acid*, and have shown, that although it is found in most cases, in vegetable products which contain tannin, it generally exists in small quantities only, and that in the usual mode of procuring it from *galls*, it is to be considered rather as a *product*, than an educt. Two methods of obtaining this acid have been resorted to; in the one, heat is applied so as to sublime it; in the other, it is procured by exposure of infusion of galls to air; in the former case the acid, as we shall immediately see, is modified; in the latter, it is produced by the action of oxygen on tannin, and it is in this way, that the purest gallic acid may be obtained; as follows:

Mix powdered galls into a thin paste with water, and expose it for four or five weeks, at a temperature between 60° and 70°, to the action of the air, observing to prevent its desiccation by the occasional addition of water: it swells and becomes mouldy, and, at the end of that period, contains a large proportion of *gallic acid:* the paste is dried by pressing out the *liquid*, (which holds scarcely any gallic acid in solution,) whilst the residue is boiled in water; the solution thus obtained is filtered whilst hot, and as it cools it deposits gallic acid, which may at once be purified by boiling it with about 8 parts of water and a fifth of its weight of animal charcoal: the filtered solution now yields pure crystallized gallic acid as it cools.

In regard to the *theory* of this change, it has been observed above, that solution of tannin undergoes no change if excluded from oxygen; but if exposed to air, it slowly absorbs oxygen, giving out an equivalent volume of carbonic acid; so that, in a few weeks, the solution contains acicular crystals of gallic acid, formed at the expense of the tannin.

Gallic acid crystallizes, in combination with water, in long silky needles, which effloresce and become anhydrous when duly exposed to a temperature of about 250°. When perfectly free from tannin, it does not affect a solution of gelatin: its taste is slightly acid and styptic, and it requires about 100 parts of water for its solution: it is somewhat more soluble in ether, and considerably more so in alcohol. According to Pelouze (*Ann. de Chim. et Phys.*, liv., 337) the equivalent of *anhydrous* gallic acid is $85 = (7\,car + 3\,h + 5\,O)$ or, it consists of

				Pelouze.
Carbon	7	42	49.4	50.10
Hydrogen	3	3	3.6	3.64
Oxygen	5	40	47.0	46.26
	1	85	100.0	100.00

and the *crystallized* gallic acid consists of

				Pelouze.
Anhydrous gallic acid	1	85	90.5	90.55
Water	1	9	9.5	9.45
	1	94	100.0	100.00

Properties of the Salts of Gallic Acid. The *gallates* have been but little examined, and much confounded with the tannates. The gallates of *ammonia*, *potassa*, and *soda*, are soluble, and colourless out of the contact of air, but absorb oxygen, and become brown. In these cases, and in the change which solution of gallic acid suffers, when exposed to air, Döbereiner states that *ulmin* is formed. The gallates of *lime*, *baryta*, and *strontia*, may be thrown down by the addition of gallic acid to the aqueous solutions of those earths, in the form of white powders, which redissolve in excess of the acid, and form silky prismatic crystals, unchanged by exposure to air. When these solutions, with excess of *base*, are exposed to air, they become discoloured.

With *persulphate of iron*, gallic acid produces a dark-blue precipitate, much more soluble than the pertannate of iron. This precipitate slowly redissolves in the supernatant solution: in a few days it becomes almost colourless, the sulphuric acid gradually resumes the greater part of the oxide of iron from the gallic acid, which separates in crystals, and the salt of iron contains a protoxide, in consequence of the decomposition of a portion of the gallic acid. These changes occur in a few minutes when the liquid is boiled. With solution of nitrate, or acetate of *lead*, gallic acid forms a permanent white precipitate, composed of

Oxide of lead	1	112	56.8
Gallic acid	1	85	43.2
	1	197	100.0

ELLAGIC ACID. This term, derived from the word *galle*, read backwards, has been applied by Braconnot (*Ann. de Chim. et Phys.*, ix., 181) to a substance produced along with gallic acid, by the exposure of moistened galls to air. Being insoluble in boiling water, it remains after the gallic acid has been extracted; and it may be dissolved out of the residue, by the action of a very weak solution of potassa, from which dilute muriatic acid throws it down in the form of a tawny powder, tasteless and almost insoluble. It does not decompose the alkaline carbonates, even at 212°. When a solution of *potassa* is dropped upon it, heat is produced, and it perfectly neutralizes the alkali: this salt, and that of *soda*, is soluble: but the *ellagate of ammonia* is, under all circumstances, nearly insoluble. Nitric acid forms a red solution with ellagic acid, and changes it into oxalic acid. According to Pelouze, *anhydrous ellagic* acid is represented by the equivalent 76. $= ({}_{7}car + {}_{2}h + {}_{4}O)$, or

Carbon	7	42	55.2
Hydrogen	2	2	2.6
Oxygen	4	32	42.2
	1	76	100.0

PYROGALLIC ACID. This acid, first noticed by Deyeux (*Jour. de Phys.*, xlii., 416) has since been studied by Braconnot (*Ann. de Chim. et Phys.*, xlvi., 206), and by Pelouze, (*ibid.* liv., 337.) It is, as its name imports, produced by the action of heat upon gallic acid, but a particular temperature is requisite for its formation, which Pelouze determined, by heating the retort containing the gallic acid, in an oil bath, to be between 410° and 420°; a little above that heat no pyrogallic acid is produced, but another distinct product, which has been called *metagallic acid.* The preparation, therefore, of pyrogallic acid requires much care as to temperature; it is best produced by half-filling a small retort with gallic acid, and heating it through the medium of an oil-bath with an immersed thermometer. It sublimes in the form of white and brilliant lamellar and anhydrous crystals, very soluble in water, alcohol, and ether, and slightly reddening litmus. Exposed to air, its aqueous solution gradually acquires colour, and, in the course of some days, is entirely resolved into what appears to be *ulmin*. It fuses at 247°, and boils at 410°, yielding a colourless vapour of a slightly balsamic odour: at 480° it blackens, and is resolved into *metagallic acid* and water. Pyrogallic acid has been analyzed by Berzelius under the name of *gallic acid*, and also by Pelouze: their experiments indicate its equivalent to be $(6\,car + 3\,h + 3\,o)$, or

				Berzelius.	Pelouze.
Carbon . . .	6 .	36 . .	57.14 . .	56.64 . .	57.61
Hydrogen . .	3 .	3 . .	4.76 . .	5.00 . .	4.70
Oxygen . . .	3 .	24 . .	38.10 . .	38.36 . .	37.69
	1	63	100.00	100.00	100.00

Pyrogallates. Ammonia, soda, and potassa, form soluble pyrogallates: that of potassa crystallizes in white rhomboidal tables. Pyrogallic acid produces no precipitate in lime, baryta, or strontia water. According to Braconnot it instantly reduces persulphate of iron to protosulphate, and the liquid acquires a reddish-brown tinge, without depositing any precipitate. If, instead of the free acid, a pyrogallate be used, or hydrated peroxide of iron, an intense blue precipitate falls. Protosulphate of iron produces an immediate blackening.

Metagallic Acid. When tannic or gallic acid is rapidly heated up to 480°, carbonic acid and water are evolved, and, instead of a sublimate of pyrogallic acid, a black, shining, and tasteless substance is formed, insoluble in water, but readily soluble in liquid ammonia, potassa, and soda, and disengaging carbonic acid, with effervescence, from the soluble alkaline carbonates. Metagallate of potassa gives black precipitates with the salts of lime, baryta, strontia, magnesia, iron, zinc, copper, lead, and silver. The equivalent of this acid appears to be $99 = (12\,car + 3\,h + 3\,o)$. The acid, as first formed, contains 1 equivalent of water.

Atomic Relations of the preceding Acids. The decomposition of gallic acid, at the temperature of 420°, is such, that 1 equivalent yields 1 of pyrogallic acid and 1 of carbonic acid; for

$$\overbrace{(7\,car + 3\,h + 5\,o)}^{\text{1 Gallic acid.}} = \overbrace{(6\,car + 3\,h + 3\,o)}^{\text{1 Pyrogallic acid.}} + \overbrace{(car + 2\,o)}^{\text{1 Carbonic acid.}}$$

and, at the temperature, of 480°, 2 atoms of pyrogallic acid yield 1 atom of metagallic acid and 3 of water; for

$$\overbrace{2\,(6\,car + 3\,h + 3\,o)}^{\text{2 Pyrogallic acid.}} = \overbrace{(12\,car + 3\,h + 3\,o)}^{\text{1 Metagallic acid.}} + \overbrace{3\,(h + o)}^{\text{3 Water.}}$$

§ X. Colorific Extractive. Colouring Matter.

The *colouring matters* of vegetables which are soluble in water, generally partake more or less of the chemical properties of *extractive*, and like that principle, are capable of being combined with, and fixed, or rendered permanent by certain bases or oxides, which, in reference to this particular case, are often termed *mordants*.

When a solution of *brown* extractive matter, for instance, is mixed with a solution of certain salts of iron, lead, or aluminum, and an alkali is added to the mixture, the metallic oxide falls in chemical combination with the extractive matter, so that the supernatant liquor remains colourless. The same thing happens with other colorific extracts; an infusion of madder, for example, when mixed with a solution of alum, and decomposed by an alkali, furnishes a *red* precipitate, and if the alumina be in excess, the residuary solution is perfectly colourless. Other coloured solutions present the same phenomena, and the coloured precipitates are, in such cases, often termed *lakes*, especially when of a red, pink, or purple tint. In these cases, an attraction is shown to exist, between the *metallic oxide* and the *colouring-matter*, and it is often the means of conferring a degree of permanence and insolubility on the latter, and modifying its hue. It has already been stated that the various forms of *lignin*, or vegetable fibre, possess a similar attraction for certain oxides: accordingly, if a piece of linen or calico be steeped in a proper solution of such oxide, a combination of the fibre and the oxide will first take place; and then, the fibre thus prepared, if immersed in a solution of colouring-extract, will combine with it, and the colour thus become fixed upon the stuff. This, in a few words, is the *theory* of the art of dyeing, with the greater number of vegetable colours, which, though in themselves fugitive, and unsusceptible of combination with the linen, cotton, or other material to be dyed, are rendered, to a greater or less extent, fixed and permanent, by the joint attraction of the base or mordant for the fibre and for the colour*.

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* The art of dyeing and calico-printing has been the subject of several separate works, to which the reader is referred for details. The following are a few of the principal points which bear upon the chemistry of the processes.

In the first place, the goods require to be thoroughly cleansed from all foreign matters and colours, which is effected by washing and *bleaching*. Warm water is at first liberally applied to remove the filth acquired in weaving; the goods, if linen or cotton, are then *bowked*, or boiled with a very weak solution of caustic potassa, washed in large quantities of water, and spread out upon the grass so as to be exposed freely to the joint agencies of light, air, and moisture; this part of the operation, which is tedious, may be much curtailed, or even superseded, by the careful application of a weak solution of chloride of lime. The bowking and exposure are alternately repeated as often as necessary; and lastly, the goods are immersed in water slightly acidulated by sulphuric acid, again thoroughly washed, and dried. By these operations, the texture of the stuffs is always more or less impaired, especially when chloride of lime is used. In respect to the *theory* of the operation of bleaching, it appears probable, that in the necessary exposure to water, air and light, or their substitute *chlorine*, *nascent oxygen* is developed, and is the destroyer of those portions of colouring-matter which are most obstinately retained. With respect to the nature of the materials or fibre to be dyed, it is found that different substances not only possess very different attractions for dye-stuffs, but they absorb the colouring-matter in very different proportions. Wool appears in this respect to have the strongest attraction for colouring-substances; silk comes next to it; then cotton; and lastly, hemp and flax. The simple operation of dyeing is generally performed upon *animal fibre*, such as wool and silk, whilst the more refined operation of printing in patterns and devices of various colours, is chiefly, though by no means exclusively, conducted upon *cotton*, or as it is usually termed, *calico*. It has been above stated, that very few colours are of such a nature as to combine with the fibre without some *intermedium*: where this is the case, they constitute what have been termed *substantive colours*: but they generally require the intervention of a *base* or *mordant*, and are called *adjective colours*. The mordants which are most frequently resorted to, are, as

There are other circumstances in which the different colouring-principles resemble each other, and which will be apparent in the following account of a few of the most important of them: they are generally impaired or destroyed by the continuous action of light, especially if aided by moisture and a certain temperature: they are also destroyed by chlorine, and by peroxide of hydrogen, and some other compounds in which oxygen is very loosely retained, and also by a few of the acids: among these, sulphurous acid is the most remarkable. The art of *bleaching* depends upon these properties, by which various colouring-matters are decomposed and destroyed, or converted into colourless compounds.

As far as their use in the arts is concerned, the *red*, *yellow*, and *blue*

has already been remarked, salts of alumina, iron, and tin. The substance to be dyed is first impregnated with the mordant, and then passed through a solution of the colouring-matter, which is thus fixed in the fibre, and its tint is often modified or exalted by the operation. That a considerable portion of the mordant is retained in the fibre of the calico or cloth dyed, has been proved by the experiments of Dr. Ure. He found that 100 parts of the ashes of Turkey-red calico (dyed by an alum mordant) afforded between 16 and 17 parts of alumina; whereas the ashes of white and washed calico only afforded a trace of that earth. (See two papers, by Dr. Ure, on the incinerated ashes of cotton-wool and calico dyed by the Turkey-red process. *Quart. Journ.*, xxi. 28—297.)

Calico-printing, which is a more refined and difficult branch of the art, is a species of topical dyeing. In this process *adjective* colours are almost always employed. The mordants, the principal of which are acetate of alumina,[1] and acetate of iron, are first applied to the calico by means of wooden blocks or copper-plates, upon which the requisite patterns are engraved. The stuff is then passed through the colouring-bath, and afterwards exposed on the bleaching-ground, or washed. The colour flies from those parts which have not received the mordant, and is permanently retained on those parts only, to which the mordant has been applied: variety of colours is produced by employing various mordants, and different colouring-materials, and by using them in various states of dilution.

White spots upon a dark ground are sometimes produced by covering the parts with wax, pipe-clay, or other materials, which prevent the contact of the colour; or citric acid, thickened with gum, is applied like a mordant with the block or plate, and prevents the retention of the colour. Sometimes the colour is discharged in places, by the application of chlorine, a process well illustrated in what are called *Bandana* handkerchiefs, of which an account will be found, by Dr. Ure, in the fifteenth volume of the *Quarterly Journal.* There is also an interesting series of papers on the subject of calico-printing, in the *Records of Science*, edited by Dr. Thomson, from which some idea may be formed of the refined and complex chemical operations which have been successfully applied to the perfection of that beautiful art.

Besides the vegetable colours which are enumerated in the text, and very many others which are occasionally resorted to, and their various *mixtures*, by which an infinite variety of *compound colours* are obtained, *metallic colours* are constantly employed both in dyeing and calico-printing. These colours are not only infinitely various, but often admirably adapted to the processes of the art. Thus the attraction of oxide of iron for different fibres, which renders it of such importance as a mordant, enables the dyer and printer to avail themselves of *Prussian-blue:* and with other metallic mordants, such as oxide of lead, copper, &c., the ferrocyanuret of potassium, iodide of potassium, chromate of potassa, arsenio-sulphurets, and various other salts, become the sources of a great variety of beautiful colours.

Instead of first applying the mordant, and afterwards the colouring-material, they are occasionally both printed together, but in these cases, particular management is requisite in the selection of the substances employed, and in the mode of their application: when this method is resorted to, the colour is often *fixed* by the application of steam at 212°.

colouring-matters are the most important; and from these, the following may be selected for more particular description, on account of their applications and chemical properties.

A. REDS.—1. MADDER. The plant which furnishes this valuable dye-stuff, (*Rubia tinctorum; Linn.*,) is common in the South of Europe, and in many parts of the Levant, and is largely cultivated in Holland: it grows to about three feet in height, and has a long spreading fibrous root, which is the part used in dyeing. It is carefully dried and cleaned, and afterwards ground into a coarse powder, which is of a dingy red or orange colour, and very apt to be deteriorated by moisture. The levantine madder, called *ligari*, *allizari*, *azale*, has a finer colour than the Dutch, but the latter is more carefully prepared and dried. When cold water is digested upon madder, it dissolves gum, sugar, *yellow* extractive, and free malic acid: the residue, boiled in water, with a small addition of carbonate of soda, yields a dark-red decoction, from which sulphuric acid throws drown the red colouring-matter: it may be purified by drying it upon blotting-paper, and solution in alcohol: to the filtered tincture a little carbonate of potassa is added to separate sulphuric acid, and when poured off from the precipitated sulphate of potassa, and evaporated, it leaves the colouring-principle in the form of a confused crystalline mass. (Kuhlmann, *Ann. de Chim. et Phys.*, xxiv., 225.) From this colouring-matter, Colin and Robiquet have obtained a crystallizable substance, which they call *Alizarine*, (*Ann. de Chim. et Phys.* xxxiv. 225.) There are several processes for its preparation, the simplest of which appears to be the following, suggested by Zenneck, (*Quart. Jour. N. S.*, v., 198):—Digest ten parts of finely-powdered madder with four parts of ether, in a close flask; the clear solution is to be distilled until the residue is thick like a syrup, and then dried upon plates in the open air, powdered, and sublimed. The sublimation is to be effected in a watch-glass, or a metallic capsule, covered by a very low cone, on which the vapours are to be condensed; the layer of matter to be sublimed must be thin, and the distance through which the vapours have to pass as small as possible; a little cotton should be placed at the orifice in the summit of the condensing-cone, and the heat applied moderate, especially at the commencement.

Alizarine, well sublimed, is in very brilliant, diaphanous, yellowish-red, acicular, quadrangular crystals; they are soft, flexible, heavier than water; have an acid taste, soften when heated, sublime at the temperature of boiling oil, and then occasion a peculiar aromatic odour. It is nearly insoluble in cold water. At common temperature, one part dissolves in 210 of alcohol, and in 160 of ether. It combines with and dissolves in alkalis, forming violet solutions; and, in fact, has all the properties of an acid. It even passes to the positive pole of the voltaic pile; and when boiled with metallic zinc, causes its oxidation, and then unites with it; 100 parts combine with and saturate 350 parts of oxide of lead: so that it has a greater saturating power than oxalic acid. Its composition *per cent.* is given as 18 carbon, 20 hydrogen, and 62 oxygen.

2. SAFFLOWER is the term given to the petals of the *Carthamus tinctorius*, or *Bastard saffron:* it is cultivated in Spain, and in many parts of the Levant, whence it is chiefly imported; but on account of its price

it is seldom used, except to give the finishing-hue to some silks, and in the preparation of the article called *rouge*. Safflower contains two colouring-matters, a *yellow* and a *red*, and as the former spoils the tint of the latter, it is removed by washing the safflower in a linen bag, in a stream of pure cold water: the residue yields the *red* colour, by digestion in a cold solution of carbonate of soda, from which it may be precipitated by a weak acid, lemon-juice being preferred. Good safflower affords about 5 *per cent.* of this product, which, according to Döbereiner, is a peculiar acid, (*carthamine*, *carthamic acid.*) It is insoluble in pure and in acidulated water, and in oils; sparingly soluble in alcohol and ether; yields a yellow solution with alkalis; and with soda a colourless crystalline salt, which acids instantly redden. This colouring-matter is easily bleached: when mixed with talc in fine powder, it forms common *rouge*.

3. Nicaragua, Peach, Brazil, Fernambouc, and Sapan Wood. These are the woods of certain species of *Cæsalpina*: they give out their colouring-matter to water: it is of different tints of red and pink, becoming yellow by acids, and blue or purple by alkalis, and easily bleached. It is soluble in alcohol. The infusion in weak citric or phosphoric acid is a good yellow dye. Various tints of violet, red, and purple, may be obtained by the action of acids and alkalis. The salts of iron render it deep blue. It is the colouring-matter of *red ink*, which is usually made by boiling about two ounces of Brazil-wood in a pint of water for a quarter of an hour, and adding a little gum and alum. (The finest *red ink* is that procured by digesting cochineal in a very weak solution of ammonia.) Nitromuriate of tin carries down the greater part of the colour of infusion of Brazil-wood, and alumina forms with it variously tinted *lakes*. The infusion of peach-wood is very well adapted for extemporaneous illustrations of the art of dyeing and calico-printing. Besides colouring-matter, the aqueous infusion of Brazil-wood contains free acetic acid, tannin, and acetates of potassa and lime, with a trace of volatile oil.

4. Logwood, Campeachy-wood. This is the wood of the *Hæmatoxylon campechianum*, a large tree which grows in various parts of the West Indies, and especially on the Bay of Campeachy, and along the American continent. It is largely imported from Jamaica, as a dye-stuff. It has a sweetish astringent taste, and a peculiar odour: an extract prepared from it is used in medicine. It contains, according to Chevreul, a peculiar colouring-principle, which he has termed *Hematin*, and which may be obtained as follows.

On the watery extract of logwood, digest alcohol for a day, filter the solution, evaporate, add a little water, evaporate gently again, and then leave the liquid at rest. Hematin is deposited in small crystals, which, after washing with alcohol, are brilliant, and of a reddish-white colour. Their taste is bitter, and astringent.

Hematin forms an orange-red solution with boiling water, becoming yellow as it cools, but recovering, when heated, its former hue. Alkali converts it first to purple, then to violet, and lastly, to brown: in which state it seems to be decomposed. Metallic oxides unite with it, forming blue compounds. Gelatin throws down reddish flocculi. Protomuriate of tin renders it lilac.

Logwood-shavings yield their colour to water and alcohol: the latter extracts it more readily than water. The colour of its dyes is red, inclining to violet or purple. Its aqueous decoction, left to itself, becomes yellowish, and at length black. Acids turn it yellow; alkalis deepen its colour, and give it a purple hue. Stuffs would take only a slight and fading colour from decoction of logwood, if they were not previously prepared with aluminous mordants. A blue colour may be obtained from it, by the addition of verdegris; but the great consumption of logwood is for *blacks*, which are obtained by alum and iron bases, and of any requisite degree of intensity.

5. Red Sandal, or Saunders Wood, is the produce of the *Pterocarpus santalinus*, and contains a deep-red colouring-matter, which is insoluble in pure water, but which may be extracted by alcohol and by alkalis. When its alcoholic solution is evaporated, it remains in the form of a red resin, fusible at 212°, and soluble in ammonia or carbonate of ammonia, from which solutions of it may be precipitated by muriatic acid: it is also soluble in acetic acid. Fine purple precipitates are thrown down in its alcoholic solution by protochloride of tin and by subacetate of lead, deep violet by sulphate of iron, scarlet by corrosive sublimate, and brown by nitrate of silver. Ether dissolves the colouring-matter of this wood more perfectly than alcohol, and water throws it down from the latter. The acetic solution of it causes an orange-coloured precipitate with gelatine. (Pelletier, *Jour. de Phys.*, lxxix., 268.)

6. Alkanet is the root of the *Anchusa tinctoria*, a species of *bugloss*, which is a native of the warmer parts of Europe, and cultivated in our gardens. The greatest quantities are raised in Germany and France. This root imparts a deep red colour to alcohol, oils, wax, and all unctuous substances. Its colouring-principle (*alcannin*, see Pelletier, *Jour. de Phys.*, lxxix., 278, and John, *Chem. Schrift.*, iv.), may be obtained by the evaporation of its ethereal tincture, or by precipitating its solution in carbonated alkalis by a dilute acid. It is insoluble in water, but soluble in alcohol and ether, and in the fat and volatile oils, to which it imparts a fine red. Its alcoholic solution is imperfectly decomposed by water. The alkalis render it blue, and the acids restore its red. It is precipitated crimson by solution of protochloride of tin; blue, by subacetate of lead; dark-violet, by the salts of iron; and pale-red, by corrosive sublimate.

The principal use of alkanet root is, that of colouring oils, unguents, and lip-salves. Wax tinged with it, and applied on warm marble, stains it of a flesh-colour, which sinks deep into the stone; the spirituous tincture gives it a deep red stain.

As the colour of this root is confined to the bark, and the small roots have more bark in proportion to their bulk than the great ones, these also afford most colour.

7. Archil, Rocella, Orselle. This is a whitish lichen, growing upon rocks in the Canary and Cape Verd Islands, which yields a purple tincture, fugitive, but extremely beautiful. This weed is imported as it is gathered: those who prepare it for the dyer, grind it so as to bruise, but not reduce it into powder, and then moisten it occasionally with urine mixed with quicklime: in a few days it acquires a blue colour; in the first state it is called *archil*, in the latter *lacmus* or *litmus*. The term

Cudbear is also often applied to this dye-stuff, a term said to be derived from the name of its discoverer, *Cuthbert* Gordon.

The chief use made of archil is for giving a bloom to other colours, which is effected by passing the dyed cloth or silk through hot water slightly impregnated with it. This bloom fades upon exposure to air: solution of tin renders it more durable, and its colour is at the same time changed toward a scarlet. Prepared archil gives out its colour to water, alkalis and alcohol*.

Litmus is used as a *test*, either by staining paper with it, or by infusing it in water, when it is very commonly called *tincture of turnsole*. The persons by whom this article was prepared, formerly gave it the name of turnsole, pretending that it was extracted from the turnsole, *Heliotropium tricoccum*, in order to keep its true source a secret. The light of the sun does, however, turn it red, even in close vessels. This tincture may be made with spirit instead of water. The tincture, or paper stained with it, is presently turned red by acids: and if it be first reddened by a small quantity of vinegar, or some weak acid, its blue colour will be restored by an alkali. (Ure's *Dictionary*.)

8. Chica Red is the colouring matter obtained from a species of *Bignonia*, and used by the American Indians to colour the skin. It is soluble in water, alcohol, and ether. (Boussingault, *Ann. de Chim. et Phys*., xxvii., 315.)

9. Animal Reds. Cochineal Red; Lac Red; Kermes. These substances are principally used in conferring upon woollen cloth the colour commonly called *scarlet*. *Cochineal* is a small insect brought from Mexico, where it is found upon different species of the *Opuntia*. The nature of this colouring matter has been investigated by MM. Pelletier and Caventou; it is united in the insect with a peculiar animal matter, fat, and some saline substances; they separated it by exposing a strong alcoholic tincture of cochineal to spontaneous evaporation; it deposited a crystalline matter, which was redissolved in alcohol and the solution mixed with its bulk of sulphuric ether; this caused it in a few days to deposit the pure colouring-principle, which they call *Carminium*: Dr. John has proposed for it the term *Coccinellin*. This substance is fusible at about 120°, very soluble in water, less so in alcohol, and insoluble in ether; the acids change its colour from purple to pale-red or yellow: the alkalis render it violet; and its colour is impaired by most saline solutions. It readily combines with alumina, forming a beautiful *lake* or *carmine*. He

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* It was the colouring-matter formerly used for tinging the spirit in thermometer-tubes, but was very liable to fade. The Abbé Nollet observes, (in the *French Memoirs* for the year 1742,) that the *colourless* spirit, upon breaking the tube, soon resumes its colour, and this for a number of times successively; that a watery tincture of archil, included in the tubes of thermometers, lost its colour in three days; and that in an open deep vessel, it became colourless at the bottom, while the upper part retained its colour. A solution of archil in water, applied on cold marble, stains it of a beautiful violet or purplish-blue colour, far more durable than the colour which it communicates to other bodies. M. du Fay says, he has seen pieces of marble stained with it, which in two years had suffered no sensible change. It sinks deep into the marble, sometimes above an inch, and at the same time spreads upon the surface, unless the edges be bounded by wax or some similar substance. It is said to make the marble somewhat more brittle, but this is probably erroneous.

obtained from 100 parts of cochineal, 50 of coccinellin, 24.5 gelatine and mucous matter, 10 waxy fat, 14 membrane, 1.5 saline matters.

The colouring-matter of cochineal is fixed upon wool by nitromuriate of tin and tartar, by which *scarlets* are produced, and alum changes the scarlet to crimson. Cotton and linen are very rarely dyed with cochineal, for, independent of its great expense, the colours are little superior to those given by madder.

Lac is a substance formed by an insect, and deposited on different species of trees, chiefly in the East Indies. The various kinds of lac distinguished in commerce, are *stick-lac*, which is the substance in its natural state, investing the small twigs of the tree; *seed-lac*, which is the same broken off; and which, when melted, is called *shell-lac*. These substances have been examined by Mr. Hatchett. The following table exhibits their component parts. (*Phil. Trans.*, 1804.)

	Stick-lac.	Seed-lac.	Shell-lac.
Resin	68	88.5	90.9
Colouring-matter	10	2.5	0.5
Wax	6	4.5	4.0
Gluten	5.5	2.0	2.8
Foreign bodies	6.5	——	——
Loss	4.0	2.5	1.8
	100	100	100

Dr. John has announced the presence of a peculiar acid in stick-lac, which he has called *laccic acid.* The lac was digested in water, the solution evaporated, and the residue digested in alcohol: the alcoholic solution was evaporated to dryness, and its residue digested in ether. The evaporation of the etheric solution leaves a yellow matter, which, being again dissolved in alcohol, and the solution mixed with water, deposits a little resin, and leaves laccic acid in solution, which, upon the addition of acetate of lead, gives a precipitate of *laccate of lead;* the latter compound, by cautious decomposition by sulphuric acid, affords the laccic acid.

Laccic acid is crystallizable, of a yellow colour, a sour taste, and soluble in water, alcohol, and ether. With potassa, soda, and lime, it forms deliquescent soluble *laccates;* with lead and mercury it produces white insoluble compounds; it occasions no precipitate in the nitrates of baryta and silver. (Thomson's *System*, ii., 177. Dr. Pearson obtained a peculiar acid from a substance called *white lac*, from Madras. He also has called it *laccic acid. Phil Trans.*, 1794.) There are two preparations of the *colouring-matter* of *lac* imported from India, under the names of *lac lake* and *lac dye.* The latter is by far the most valuable, and by skilful management may be employed in dyeing scarlet as a substitute for cochineal. It is to be regretted that the preparation of this valuable dye-stuff is not more carefully attended to.

Kermes, or the *Coccus ilicis*, a small insect found in many parts of Asia, and in the South of Europe; and the *Coccus Polonicus*, found adhering to the roots of *Polygonum*, and employed as a dye-stuff in Poland and in Turkey, also contain a red colouring-principle. The scarlets and crimsons which they produce, are said to be brilliant and permanent. Tartar and solutions of tin are used to produce scarlet; and aluminous bases, and soap, for crimson.

B. YELLOWS.—1. QUERCITRON BARK. This is the bark of the *Quercus tinctoria*, or *Quercus nigra* of North America: it was first introduced into England by Dr. Bancroft, (*Philosophy of Permanent Colours*, London, 1813,) and is now one of our most important dyeing-materials. Its colouring-principle, which amounts to about 8 *per cent.*, may be extracted by water; a quantity of tannin is at the same time taken up, which would be prejudicial, and therefore glue, bladder, or some similar gelatinous membrane is added to the infusion, by which the tannin is abstracted. The yellow colorific extract may then be precipitated in combination with alumina, or with oxide of tin. With the salts of iron it gives a variety of olive and drab tints, dependent upon the presence of more or less tannin, and the degree of dilution.

2. FUSTIC. This is the wood of the *Morus tinctoria*, a large tree which grows in many parts of the West Indies, and on the American continent. It yields 9.1 colouring-matter with some gallic acid, 4 tannin, 2 gum, 9 resin, 74 lignin. (George, as quoted by Berzelius.) Its decoction is orange-coloured, and is improved as a yellow dye, by the addition of gelatin. Alkalis deepen its colour, and acids render it paler. Acetate of lead and protochloride of tin give deep-yellow precipitates with it, the tint of which is brightened by tartar and alum.

WELD (*Reseda luteola*). This is a slender plant, growing to the height of about three feet, and cultivated for dyers. When ripe it is cut and dried. Its decoction is of different shades of yellow, according to its strength. Alkalis deepen its tint, and acids render it paler. Alum, tartar, and solutions of tin, brighten it, and give it more or less of a deep-lemon tint. *Dyers' Broom* (the *Genista tinctoria*, Linn.,) and the American *Golden Rod* (*Solidago canadensis*), also contain a yellow extractive, from which yellow dyes are obtained. A water-colour, called *weld-yellow*, is much used by paper-hanging manufacturers. It is the colouring-matter of weld precipitated with an earthy base. It is prepared as follows:—Into a copper-vessel put four pounds of fine washed whiting, and as much soft-water, and boil them together, stirring them with a deal stick, till the whole forms a smooth mixture: then add gradually twelve ounces of powdered alum, still stirring, till the effervescence ceases, and the whole is well mixed. Into another copper put any quantity of weld, with the roots uppermost; pour in soft water enough to cover every part containing seed; let it boil, but not more than a quarter of an hour; take out the weld, and set it to drain; and pass the whole of the liquor through flannel. To the hot mixture of chalk and water, add as much of this decoction as will produce a good colour, keep it on the fire till it boils, and then pour it out into a wooden or earthen vessel. The next day the liquor may be decanted, and the colour dried on chalk. (Ure's *Dictionary*.)

4. ANNOTTO (*Roucou. Orlean.*) This article is procured from the seeds of a large tree, the *Bixa orellana*. When ripe they are bruised, soaked, and beaten into a pulp, which, after due fermentation, is boiled with water, during which it throws up a scum, which is collected, dried, and made into cakes or rolls, of 2 or 3 pounds weight: in this state it comes into our market from Cayenne, and other parts of America. Its colouring-

matter is soluble in water, and more so in alcohol and alkaline liquors: it has a disagreeable smell and taste. It is a powerful dye, and is used also to colour various varnishes, and to give the deep-orange tint to Cheshire cheese. (Boussingault, *Ann. de Chim. et Phys.*, xxviii., 440.)

5. Turmeric is the root of the *Curcuma longa.* It yields a yellow colour, slightly to water, but very abundantly to alcohol, and to alkaline solutions: the latter impart to it a deep-brown tint, hence its use in the laboratory as a *test.* Acids, with some few exceptions, (such as the boracic, and muriatic acid gas, which tinge turmeric paper brown,) render it bright yellow. It is much used in cookery to give yellow tints, and is an ingredient in *curry-powder.*

6. Saffron. The stigmata of the *Crocus sativus*, form the article known in commerce under this name. Bouillon la Grange and Vogel have given the term *Polychroite* to its colouring-principle, (*Ann. de Chim.*, lxxx., 198,) from the variety of colours which it produces under the influence of various reagents. But Henry (of Paris) has shown that polychroite is a compound of extractive and essential oil, and that the extract alone is not possessed of any important peculiarities.

C. Blues. The blue colouring-matter of plants, is chiefly resident in the petals of flowers, but the fruits and other parts which contain purple or red juices, may generally be rendered blue by the action of an alkali, or other base, which saturates the acids that are present; so that the original colouring-principle often appears in these cases to possess a blue colour, reddened by the action of one or more of the vegetable acids.

The colouring-matter of most *flowers* is extremely fugitive, and is generally much changed by mere exsiccation. They usually communicate their colour to water: the infusion of *blue* flowers is generally reddened by acids, and changed to green or yellow by alkalis; that of *yellow* flowers is made paler by acids, and alkalis render it brown: the *red* infusion of many flowers is exalted in tint by acids; and changed to purple, and in some instances to green, by alkalis: so that probably one and the same principle gives colour to several of the blue and red flowers, but the presence of acid in the latter produces the red; the petals of the red rose, triturated with a little carbonate of lime and water, give a blue liquor; alkalis render it green, and acids restore the red.

A colouring-matter, analogous to that of the violet, exists in the petals of red clover, in the red tips of those of the common daisy, of the blue hyacinth, the hollyhock, lavender, in the inner leaves of the artichoke, and in numerous other flowers; reddened by an acid, it colours the skin of several plums, and the petals of the scarlet geranium and pomegranate. Some flowers which are red, become blue by merely bruising them; this is also the case with the colouring-matter of red cabbage-leaves, and of the rind of the long radish. Mr. Smithson has suggested that the reddening acid is in these cases the carbonic, which escapes on the rupture of the vessels which enclose it.

The petals of the common *corn-poppy*, rubbed upon paper, give a purple stain, little altered by ammonia or carbonate of soda, but made green by caustic potassa. The infusion of poppy-petals in very dilute muriatic acid, is florid red; chalk added, renders it of the colour of port wine; carbonate of soda in excess gives the same colour, but excess of potassa changes it to green and yellow.

The colouring-matter of *fruits* seems, in most cases, to bear a strong resemblance to that of flowers. The red juice of the mulberry was found to exhibit the same characters as the colouring-principle of the wild poppy; carbonated alkalis render it blue, but caustic potassa changes it to green and yellow: the juice of red currants, cherries, elder-berries, and privet-berries, and the skin of the buckthorn-berry, appear to contain a similar colouring-principle. The unripe berries of the buckthorn furnish a juice, which, when inspissated, is known under the name of *sap-green.* It is soluble in water, and rendered yellow by carbonate of soda and caustic potassa; the acids redden it, and carbonate of lime restores it to green, which is therefore probably the proper colour of the substance. (Smithson, *Phil. Trans.*, 1818.) Black currants, the common blackberries, the ripe berries of the Portugal laurel, and several other common fruits and berries, contain similar colouring matters.

Indigo. The most important blue colouring-matter is the substance called *Indigo;* it is evidently a vegetable principle *sui generis*, but from its value as a dye-stuff, I shall place it among the *colorific extractive principles;* indeed, in its original state, as it exists in the sap of the plants whence it is obtained, it appears to be as nearly allied to extractive, as to any of the other proximate principles; but as we shall presently find, its character as a proximate principle, and its ultimate or elementary composition, are distinct and peculiar.

Indigo is obtained chiefly from different species of *Indigofera*, an American and Asiatic plant, cultivated as a source of this article; it is also obtained from the *Nerium tinctorium;* and from some species of *Isatis*, or *woad.* The *dye* is extracted either from the fresh or dried plant, by suffering it to ferment with water, during which it undergoes chemical changes, which ultimately cause its deposition in the form of a blue feculent deposit, which is collected and dried. In regard to the details of its manufacture, two papers will be found in the *Quarterly Journal of Science*, (vols. v. and vi., *new series*, pp. 296 and 265,) in which the principal steps of the operation, and the probable nature of the results, are explained. The general characters of indigo, as it is found in commerce, are the following: it occurs in square cakes, or cubical masses of a deep-blue colour, and generally containing about 50 *per cent.* of pure colouring-matter, which is perfectly insoluble in water; when heated to between 500° and 600°, it affords a sublimate in the form of a blue smoke, which, on condensation, forms acicular crystals, amounting in weight to 18 or 20 *per cent.* of the original indigo. It is soluble in concentrated sulphuric acid. This solution is usually called *Saxon*, or *liquid blue*, and is used as a substantive colour for dyeing cloth and silk. Substances which powerfully attract oxygen render indigo green, and by exposure to air, it again acquires a blue colour. In this green state, indigo is soluble in the alkalis, and the solution is commonly employed for dyeing calico. A bath for this purpose may be made by mixing one part of indigo, two parts of sulphate of iron, and two of lime, in a sufficient quantity of water: in this case, the sulphate of iron is decomposed by a portion of the lime. The protoxide of iron thus produced becomes peroxidized at the expense of the indigo, which is rendered green and soluble in the alkaline liquor; cotton steeped in this solution acquires a green colour, which, by exposure to air, and washing in water acidulated with sulphuric acid, becomes a permanent blue. A little iron or zinc thrown into diluted sulphate of indigo changes or destroys the colour in consequence of the evolution of hydrogen; the colour is also quickly impaired and destroyed by chlorine.

The analysis of indigo, to ascertain the proportion of *colouring-matter*, which varies much in different samples, may be performed by the successive action of water, alcohol, and muriatic acid. (Chevreul, *Ann. de Chim.*, lxvi., 20.) 100 parts of Guatimala indigo, thus treated, afforded

To Water .	Green matter combined with ammonia . .	12
	Deoxidized indigo	
	Extract	
	Gum	
To Alcohol .	Green matter	30
	Resin	
	A trace of indigo	
To Muriatic Acid	Red resin	6
	Carbonate of lime	2
	Oxide of iron	2
	Alumina	
Residue . .	Silica	3
	Pure indigo	45
		100

Indigo has also been subjected to an interesting series of experiments by Berzelius (*Ann. de Chim. et Phys.*, Nov. *et* Dec., 1827), who found its usual constituents to be four distinct substances: viz., 1. gluten; 2. a peculiar brown substance, apparently resembling extract; 3. a red substance, which gives a white sublimate when heated in close vessels; 4. indigo blue. 1. The substance which Berzelius terms *Gluten*, is soluble both in alcohol and water, and was obtained by digesting powdered indigo in dilute sulphuric acid, neutralizing the solution by chalk, filtering, evaporating to dryness, and digesting the residue in alcohol. 2. The *Brown matter* was taken up from the indigo (freed as above from gluten) by potassa, and neutralizing the solution by sulphuric acid; this occasions a precipitate containing a peculiar brown matter. 3. Upon the indigo, purified by dilute acid and by the action of solution of potassa, strong alcohol was digested, which takes up a *red substance*, insoluble in water and alkalis, soluble in concentrated sulphuric acid, and in nitric acid, and which, when heated in vacuo, yields a gray crystalline sublimate. 4. The substance remaining after the action of the above solvents is the real colouring-matter of the indigo, or *indigo-blue*, and is that which forms the purple vapour and sublimate above alluded to. It forms a deep-blue solution of great intensity with sulphuric acid, and especially with the fuming and partly anhydrous acid (Nordhausen acid), and is, in fact, the principal ingredient in the sulphuric dyeing-liquor already mentioned.

The action of sulphuric acid upon indigo, has been investigated by Mr. Crum. (*Ann. of Phil., N. S.*, v., 81). The concentrated acid does not merely dissolve it, but, in the course of twenty-four hours, alters its properties; it at first becomes yellow, in consequence probably of the abstraction of the elements of water, for much heat is evolved, and the addition of water instantly restores the blue tint. Nothing is given off or absorbed, nor is carbon precipitated. When the sulphuric solution is neutralized by potassa, an intensely-blue precipitate falls, soluble in water, but insoluble in saturated solutions of the salts of potassa; it was, therefore, purified by alternate washing with solution of acetate of potassa and alcohol. When dry it acquires a copper-colour, is very hygrometric, soluble in 140° of cold, and in a smaller proportion of hot, water. The cold solution, even when largely diluted, furnishes insoluble precipitates with salts of potassa, soda, lime, baryta, strontia, lead, and mercury. This substance has been called *Cerulin*, and exists in the precipitate as a *ceruleo-sulphate of potassa:* it appears to be a hydrate of indigo, in which one proportional of indigo is combined with four of water.

By limiting the action of the acid upon the indigo to three or four hours (or at 100° to 20 minutes), different results are obtained. One part of purified indigo was shaken in a phial with ten of sulphuric acid till it became green, it was then poured into water, and filtered. The first washings of the substance upon the filter are to be rejected; but when the liquid passes of a blue colour, solution of chloride of potassium may be added, which throws down a *purple* precipitate, called by Mr. Crum, *Phenicin* (from φοινιξ). This substance is soluble in water and alcohol; it is converted by sulphuric acid into cerulin; it is precipitated by almost all saline substances of a purple colour; it appears to contain one proportional of indigo and two of water.

INDIGOGENE. The extraordinary change which indigo, or rather its colouring-principle, undergoes by the action of deoxidizing agents, has been studied by Liebig. (*Ann. de Chim. et Phys.*, xxxv.) He obtained *white* or *deoxidized* indigo (*indigogene*), as follows: 1½ part of pure indigo, 2 parts of proto-sulphate of iron, 2½ parts of hydrate of lime, and from 50 to 60 parts of water, were digested together for 24 hours in a close vessel, which had previously been filled with hydrogen. The clear liquor over the sulphate of lime and oxide of iron had a yellowish-red colour, and was separated by a siphon filled with hydrogen, and mixed with diluted muriatic acid, containing some sulphite of ammonia dissolved; a dense white precipitate was formed, becoming blue in the air. This was gathered in a filter out of contact of air, and washed with boiled water containing sulphite of ammonia in solution, and dried at 212°, in close vessels through which a current of hydrogen was continually passed. The upper surface of the mass became of a blue colour, but the lower remained of a dull-white. This *white* substance was called *Indigogene.* It did not change colour in dry air, but under water became of a deep-blue, which, by drying, assumed a coppery appearance. The blue substance volatilized by heat, without leaving any residue, forming purple vapours, which condensed, when cold, into crystals differing in nothing from sublimed indigo. Indigogene dissolves in alkalis without neutralizing them: it is also soluble in alcohol, but insoluble in water or acids.

A given quantity of this indigogene was acted upon by ammonia, and the weight of the undissolved blue portion ascertained; it appeared that the weight of the pure portion dissolved was 0.404 grammes (6.224 grains). The solution was put into an inverted jar, over mercury, and oxygen gas gradually passed in until absorption ceased, and then the liquid containing the precipitated indigo was evaporated to dryness at 212°. The weight of the substance was increased to 0.047, *i. e.* 11.5 *per cent.*

Not having obtained indigogene *perfectly* pure, M. Liebig did not attempt to analyze it for the ultimate composition. He remarks, that indigo is perhaps the only organic body from which one of its constituent parts may be taken without total decomposition; and which, by oxidation, passes to the state of a body having much analogy with peroxides.

L. Gmelin, in his *Handbuch*, gives the following as the probable composition of white deoxidized indigo, or indigogene:

Nitrogen	1	14	12.07
Carbon	15	90	77.59
Hydrogen	4	4	3.45
Oxygen	1	8	6.89
Deoxidized indigo	1	116	100.00

and if *indigo-blue* be regarded as a *protoxide of indigogene*, the following view may be taken of its composition.

				Crum.	De Royer and Dumas.	Ure.
Nitrogen	1	14	11.29	11.26	13.74	10.00
Carbon	15	90	72.58	73.22	73.30	71.37
Hydrogen	4	4	3.23	2.92	2.80	4.38
Oxygen	2	16	12.90	12.60	10.16	14.25
Indigo-blue	1	124	100.00	100.00	100.00	100.00

and regarding *phenicin* as a *bihydrate*, and *cerulin* as a *quadrihydrate of indigo**, they will be constituted as follows:

				Crum.				
Nitrogen	1	14	9.86	9.91	Indigo-blue	1	124	87.33
Carbon	15	90	63.38	64.62				
Hydrogen	6	6	4.22	3.98	Water	2	18	12.67
Oxygen	4	32	22.54	21.49				
Phenicin	1	142	100.00	100.00	or	1	142	100.00

				Crum.				
Nitrogen	1	14	8.75	8.79	Indigo-blue	1	124	77.5
Carbon	15	90	56.25	57.18				
Hydrogen	8	8	5.00	4.71	Water	4	36	22.5
Oxygen	6	48	30.00	29.32				
Cerulin	1	160	100.00	100.00		1	160	100.0

ACTION OF NITRIC ACID ON INDIGO. The action of nitric acid on indigo was first examined by Mr. Hatchett (*Additional Experiments on Artificial Tannin, Phil. Trans.*, 1805). He found that this acid, diluted with about two parts of water, produced much effervescence when poured on powdered indigo, and gradually dissolved it; the solution, evaporated to dryness, left a yellowish residue, soluble in water, of an intensely-bitter taste, and composed partly of artificial tannin, and partly of a peculiar *bitter principle* combined with ammonia.

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* According to Berzelius, the action of sulphuric acid upon indigo is attended by the production of *indigo purple, sulphate of indigo,* and *hyposulphate of indigo.*

Carbazotic Acid. The action of nitric acid on indigo has subsequently been studied by Liebig, who finds a peculiar acid among the results afforded by treating indigo with excess of nitric acid, which he terms *Carbazotic acid*, and respecting the production and properties of which he has given the following details:

A portion of the best indigo is to be broken into small fragments, and moderately heated with eight or ten times its weight of nitric acid, of moderate strength. It will dissolve, evolving an abundance of nitrous vapours, and swelling up in the vessel. After the scum has fallen, the liquid is to be boiled, and nitric acid added, whilst any disengagement of red vapours is occasioned by it. When the liquid has become cold, a large quantity of semi-transparent yellow crystals will be formed, and if the operation has been well conducted, no artificial tannin or resin will be obtained. The crystals are to be washed with cold water, and then boiled in water sufficient to dissolve them. If any oily drops of tannin form on the surface of the solution, they must be carefully removed by touching them with filtering-paper. Then filtering the fluid, and allowing it to cool, yellow brilliant crystalline plates will be obtained, which will not lose their lustre by washing. To obtain the substance perfectly pure, the crystals must be re-dissolved in boiling water, and neutralized by carbonate of potassa. Upon cooling, a salt of potassa will crystallize, which should be purified by repeated crystallizations. On mixing the first mother-liquor with water, a considerable brown precipitate will be obtained, which being dissolved in boiling water, and neutralized by carbonate of potassa, will also furnish a quantity of the salt. All the potassa-salt obtained in these operations is to be re-dissolved in boiling water, and nitric, muriatic, or sulphuric acid added; as the solution cools, the peculiar substance will be observed to form very brilliant plates of a clear yellow colour, generally in equilateral triangular forms. Sometimes crystals are not formed after the action of the nitric acid on the indigo, in which case, the liquor must be evaporated, and water added, when the substance will precipitate, and must be purified as already described. Four parts of indigo yield one of the pure substance.

When the substance is heated, it fuses, and is volatilized without decomposition; when subjected to a sudden strong heat, it inflames without explosion, its vapours burning with a yellow flame, and a carbonaceous residue remaining. It is but little soluble in cold water, but much more in boiling water; the solution has a bright-yellow colour, reddens litmus, has an extremely bitter taste, and acts like a strong acid on metallic oxides, dissolving them, and forming peculiar crystallizable salts. Ether and alcohol dissolve the substance readily. When fused in chlorine or with iodine, it is not decomposed, nor does solution of chlorine affect it. Cold sulphuric acid has no action on it; when hot it dissolves it, but water separates the substance without alteration. Boiling muriatic acid does not affect it, and nitro-muriatic acid only with great difficulty. These results show that no nitric acid is present in the substance, and other experiments prove that no oxide of nitrogen exists in it; it contains no oxalic or other organic acid, for when its salt is boiled with chloride of gold, the latter is not reduced. When heated to redness with oxide of copper, it gave a mixture of nitrogen and carbonic acid, in the exact proportion of one volume of the former to five of the latter. This was a constant result, and in no case was any sulphuric or other acid left in the copper. This compound, therefore, called *carbazotic acid*, is represented by Liebig as destitute of hydrogen, and as consisting of

				Liebig. Mean of 4 expts.
Nitrogen	3	42	16.67	16.2
Carbon	15	90	35.71	35.0
Oxygen	15	120	47.62	48.8
	1	252	100.00	100.0

THE CARBAZOTATES are crystallizable, bitter, and deflagrate or explode when heated. They detonate much more powerfully when heated in close vessels, than when heated in the air; and it is curious to observe, that those with bases yielding oxygen most readily, are those which explode with least force. By heating some of the salts previously mixed with chloride of potassium, &c., to retard the action, it appeared that no carbonic oxide, but only carbonic acid and nitrogen were evolved during their decomposition by heat.

CARBAZOTATE OF AMMONIA forms very long, flattened, brilliant, yellow crystals, very soluble in water. Heated carefully in a glass tube, it fuses, and is volatilized without decomposition; heated suddenly, it inflames without explosion, and leaves much carbonaceous residue.

CARBAZOTATE OF POTASSA crystallizes in long yellow quadrilateral needles, semi-transparent and very brilliant; it dissolves in 260 parts of water at 60° Fahr., and in much less boiling water: a saturated boiling solution becomes a yellow mass of needles, from which scarcely any fluid will run. Strong acids decompose it; yet when an alcoholic solution of carbazotic acid is added to a solution of nitre, crystallized carbazotate of potassa, after some time, precipitates. Alcohol does not dissolve it. When a little is gradually heated in a glass tube, it first fuses, and then suddenly explodes, breaking the tube to atoms; traces of charcoal are observed on the fragments. This salt precipitates a solution of the protonitrate of mercury, but not salts containing the peroxide, or those of copper, lead, cobalt, iron, lime, baryta, strontia, or magnesia. The slight solubility of this salt supplies an easy method of testing and separating potassa in a fluid. Even the potassa in tincture of litmus may be discovered by it; for, on adding a few drops of carbazotic acid, dissolved in alcohol, to infusion of litmus, crystals of the salt gradually separated. The saturated solution of the salt at 50° Fahr. is not troubled by chloride of platinum. The salt contains no water of crystallization. It was analyzed by converting a portion of it into chloride of potassium by muriatic acid. Its composition is,

				Liebig.
Potassa	1	48	15.9	16.21
Carbazotic acid	1	252	84.1	83.79
	1	300	100.0	100.00

CARBAZOTATE OF SODA crystallizes in fine silky yellow needles, having the general properties of the salt of potassa, but soluble in from 20 to 24 parts of water, at 59°.

Carbazotate of Lime, obtained like the salt of baryta, forms flattened quadranglar prisms, very soluble in water, and detonating like the salt of potassa.

Carbazotate of Baryta is obtained by heating carbonate of baryta and carbazotic acid with water. It crystallizes in quadrangular prisms of a deep colour, and dissolves easily in water. When heated, it fuses, and is decomposed with very powerful explosion, producing a vivid yellow flame: the explosion is as powerful as that of fulminating silver. A solution of chloride of potassium, to which carbazotate of baryta has been added, produces a precipitate of the potash-salt, and not more than 1½ *per cent.* of potash remains in solution. Carbazotate of baryta contains

				Liebig.					Liebig.
Baryta	1	77	23.5	23.8		1	77	20.80	20.87
Carbazotic acid	1	252	76.5	76.2		1	252	66.65	66.63
Water						5	45	12.55	12.50
Dry	1	329	100.0	100.0	Cryst.	1	374	100.00	100.00

Carbazotate of Magnesia forms very long indistinct needles, of a clear yellow colour; is very soluble, and detonates violently.

Proto-Carbazotate of Mercury is obtained in small yellow triangular crystals, by mixing boiling solutions of the carbazotate of potassa or soda, and proto-nitrate of mercury. It requires more than 1200 parts of water for its solution: for its perfect purification, it should be heated with a solution of chloride of potassium, the insoluble portion separated whilst the liquid is hot, and the peculiar salt allowed to deposit as the temperature falls. When heated, it behaves like the salt of silver. It consists of

				Liebig.
Protoxide of mercury	1	210	45.46	45.09
Carbazotic acid	1	252	54.54	54.91
	1	462	100.00	100.00

Carbazotate of Lead may be formed by decomposing a salt of lead by carbazotate of potassa or soda; it is a yellow powder, but slightly soluble, and detonating by heat.

Carbazotate of Copper is prepared by decomposing sulphate of copper by carbazotate of baryta; it crystallizes with difficulty, the crystals being of a fine green colour; it is deliquescent; when heated, it is decomposed without explosion, and even without inflammation.

Carbazotate of Silver. Carbazotic acid readily dissolves oxide of silver, when heated with it and water; and the solution, gradually evaporated, yields starry groups of fine acicular crystals of the colour and lustre of gold; the salt dissolves readily in water; when heated to a certain degree, it does not detonate, but flashes like gunpowder.

Indigotic Acid. When indigo is acted on by *dilute* nitric acid, a peculiar acid, which appears perfectly distinct from the above, was obtained by Chevreul, and has been examined more in detail by Dr. Buff. It has been termed *Indigotic acid.*

To obtain it, nitric acid, of sp. grav. 1.285, was diluted with rather more than its weight of water, heated in a retort, and small portions of indigo in fine powder added as long as sensible effervescence was produced; a little water was added from time to time, to prevent the formation of carbazotic acid. The yellow liquid was separated, whilst hot, from the resinous matter, and by cooling deposited crystals of this acid of indigo. These were boiled with oxide of lead, filtered, and the salt produced decomposed by sulphuric acid whilst hot; on cooling, the liquor deposited the acid of indigo in yellowish-white crystals; these were separated, dissolved in hot water, neutralized by carbonate of baryta, the solution concentrated, and allowed to cool; yellow acicular crystals of a barytic salt were obtained, which, being washed with cold water, dissolved in hot water, and decomposed by acids, gave acicular crystals of this acid of indigo, white as snow; they were collected, and washed upon a filter, and shrank into a small space when dry, losing almost entirely their crystalline aspect.

Indigotic acid is white, having the lustre of silk; it has a weak, acid, bitter taste, reddens litmus, dissolves in any quantity in boiling water or alcohol, forming colourless solutions, but requires 1000 parts of cold water for its solution. It is volatile, and, being heated in a tube, fuses and sublimes without decomposition. When the fused acid is cooled, it crystallizes in six-sided plates. In the air it burns with a bright flame, evolving much smoke. Nitric acid changes it into carbazotic acid. Neither chlorine, nor solution of chlorine, has any effect upon it. It gives a blood-red colour to solutions of the persalts of iron.

When decomposed by heat and oxide of copper, it yields nitrogen and carbonic acid; the proportions of these gases in volume being 1 and 15. These are exactly the same proportions which, according to Mr. Crum and Dr. Buff, are given by pure indigo itself: so that the nitrogen and carbon are probably in the same relation both in indigo and the acid of indigo. Dumas also states that the *indigotic acid* may be regarded as an oxide of indigo, but different authorities differ as to its equivalent. According to Buff, the neutral *indigotate of lead* consists of 37.38 oxide of lead + 62.62 indigotic acid, and accordingly the equivalent 180 may be assumed as that of indigotic acid, and it may be regarded as containing

				Buff.	Dumas.
Nitrogen	1	14	7.75	7.588	7.73
Carbon	15	90	50.00	49.575	48.23
Hydrogen	4	4	2.25		2.76
Oxygen	9	72	40.00	42.837	41.28
	1	180	100.00	100.000	100.00

Indigotate of Ammonia forms yellow, transparent, acicular prisms, much resembling the carbazotate of potassa, partly volatile without decomposition, and easily soluble in water.

Indigotate of Potassa. Orange-coloured, silky, opaque, clustered needles, anhydrous, and very soluble.

Indigotate of Soda. Yellow, and very soluble.

Indigotate of Baryta. When carbonate of baryta is boiled in a solution of indigotic acid, and filtered, a yellow bitter solution is obtained, which yields yellow anhydrous fibrous crystals, composed of $(B + 1\frac{1}{2}\ ind'.)$ Ammonia added to this solution throws down a yellow powder, consisting of $(5\ B + 3\ ind'.)$

Indigotate of Lime, of Strontia, and of Magnesia, are yellow and soluble salts.

Indigotate of Lead is thrown down in the form of a bulky pale-yellow precipitate, when a solution of indigotate of potassa is gradually added to excess of a hot solution of nitrate of lead. When washed with cold water, and dried at 212°, it forms a pale-yellow crystalline mass, rather more soluble in cold water than indigotic acid, and easily soluble in hot water. When digested in ammonia it becomes a yellow insoluble subsalt. These indigotates of lead consist of

				Buff.					Buff.
Oxide of lead	1	112	38.3	37.38		2	224	55.5	56.14
Indigotic acid	1	180	61.7	62.62		1	180	44.5	43.86
Neutral	1	292	100.0	100.00	Subsalt	1	404	100.0	100.00

Indigotate of Iron. Indigotic acid dissolves hydrated peroxide of iron, and forms a salt which may be obtained in dark-red, or nearly black crystals, slowly soluble in cold water. The solution is dark-red.

Indigotate of Copper. Oxide of copper is soluble in indigotic acid. The salt separates from its solution in boiling water, in the form of a green flocculent precipitate.

Indigotate of Mercury. Indigotate of potassa produces a pale-yellow precipitate in protonitrate of mercury, which is insoluble in cold, and sparingly soluble in boiling water. From Buff's analysis it appears to be a sesquisalt $= (\mathrm{Hg} + 1\frac{1}{2}\, ind'.)$

Indigotate of Silver. Solution of indigotic acid readily dissolves oxide of silver: the solution blackens when long boiled. (Chevreul.) Neither indigotic acid, nor indigotate of potassa, produce any precipitate in nitrate of silver. Indigotate of silver forms pale-red acicular crystals, difficultly soluble in cold water. (Buff.)

§. XI. Fixed or Fat Oils. Wax.

The proximate principles that we are now about to examine, are those in which hydrogen predominates (p. 891), and which are characterized by the readiness with which they burn with flame: they are ternary compounds of carbon, hydrogen, and oxygen, and are applicable to numerous useful purposes.

Fixed Oils are generally obtained by pressure from certain seeds, such as the almond, linseed, and many others, and from the olive. The specific gravity of the fixed oils is below that of water, varying from 0.918 to 0.936. They are viscid or unctuous, and insipid, or nearly so; they generally congeal at a temperature not so low as that required to freeze water, though a few remain liquid at very low temperatures. This is the case with linseed oil. A few of them are solid at the ordinary temperatures, and have been called *vegetable butters*. They are insoluble in water, but by the aid of mucilage may be diffused through it, forming *emulsions*.

If oil, which has been congealed by cold, be submitted to pressure between folds of bibulous paper, a dry, concrete, fatty matter is obtained, which Chevreul has called *Stearine**, (from στεαρ, *tallow*,) the paper absorbs a fluid matter, which does not congeal at a much lower temperature, and which, though it does not become rancid, acquires viscidity by exposure to air. This fluid part he has called *Elaine* or *Olein*, (from ελχιον, *oil*.) The relative proportions of these principles differ in the different oils. (*Ann. de Chim.*, tom. xciii. xciv.) See *Animal Oils*.

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* According to Lecanu (*Ann. de Chim. et Phys.*, lv., 192), the stearine of vegetable oils differs from that of animal fats, and is analogous to *margarine*.

The greater number of the fixed oils undergo little other change by exposure to air than that of becoming somewhat more viscid, and acquiring a degree of rancidity. In this state they contain free acid, and redden vegetable blues. Some few, such as linseed and nut oil, and the oils of the poppy and hempseed, become covered with a pellicle, and, when thinly spread upon a surface, instead of remaining greasy, become hard and resinous; these are termed *drying oils*, and their drying quality is much improved by boiling them upon a small quantity of litharge. The quantity of oxygen absorbed by some of the oils is very considerable. Saussure exposed nut oil, for eight months, to oxygen gas; at first the absorption was trifling, but in the course of ten days it had taken up 60 times its volume, and in three months 145 times its volume, the absorption being most rapid in warm weather. It is well known that cotton and hemp, soiled with certain oils, are liable to spontaneous ignition; and Berzelius plausibly refers the phenomenon to the heat excited by the absorption of oxygen. No water was produced in Saussure's experiments, but carbonic acid was evolved, and the oil lost its greasy character and assumed a gelatinous appearance. (See some observations on the spontaneous combustion of cotton goods, by Dr. M. Hall, *Quarterly Journal, O. S.*, v., 367.)

These oils cannot be volatilized without decomposition, which takes place at a temperature of about 600°, and water is copiously formed, attended by the separation of carbonaceous matter, which causes the oil to blacken and grow thick; a portion of acetic acid is also at the same time formed. If the vapour be collected, it is found acrid, sour, and empyreumatic; it was formerly employed in pharmacy, under the name of *philosophers' oil;* and as it was often obtained by steeping a brick in oil, and submitting it to distillation, it was also called *oil of bricks.* Passed through a red-hot tube, the fixed oils furnish a very large proportion of carburetted hydrogen gas; and when burned in the wicks of lamps they suffer a similar decomposition, and water and carbonic acid are the products of their combustion. The results of the distillation of the fixed oils have been examined by Dupuy, and by Bussy and Lecanu. The former subjected olive oil to its boiling-point in a distillatory apparatus; white vapours passed over, which condensed into a liquid that became concrete on cooling; a fluid empyreumatic oil was also formed; and there remained a scanty portion of charcoal in the retort. The concrete portion was a mixture of oleic and margaric acids with a peculiar acrid, volatile principle; sebacic acid, and another acid matter, were also formed.

Bussy and Lecanu (*Ann. de Chim. et Phys.*, xxxi., xxxiii., and xxxiv.) distilled poppy oil at a temperature a little below 400°; it exhaled an acrid odour, and yielded about one-third its weight of an oil which concreted on cooling, (a mixture chiefly of margaric, oleic, and benzoic acids.) This was succeeded by a liquid oil, which became turbid on exposure to air, was little soluble in alcohol, and not acted upon by the alkalis. Lastly, when the retort became red-hot, a solid of the colour of realgar sublimed, which was without smell or taste, fusible in boiling water, and soluble in boiling alcohol and cold ether. Carburetted hydrogen, carbonic oxide, and carbonic acid, were also produced.

Chlorine effects a singular change in some of the fixed oils, converting them into a substance resembling hard tallow or wax. This is especially the case with castor oil. Muriatic acid is at the same time formed. Sulphur and phosphorus are soluble in the fixed oils; and with the former, linseed oil forms a brown fetid solution, known in Pharmacy as *balsam of sulphur.*

The stronger acids modify and decompose the fixed oils, and various products are the result, especially the stearic, margaric, and oleic acids, to which we shall afterwards advert. When olive oil is carefully mixed with sulphuric acid, so as to avoid the heating of the mixture, a thick brown compound is formed, from which water separates the oil in an altered state, and retains in solution a peculiar compound (of hyposulphuric acid and organic matter?), which Chevreul has termed *sulpho-adipic acid.* When heat is applied to the mixture of sulphuric acid and oil, it blackens, sulphurous acid is evolved, and a coaly residue containing artificial tannin remains. (Hatchett.) Concentrated nitric acid produces very complicated changes upon these oils, and sometimes the mutual action is so energetic, that the mixture inflames: by long boiling with dilute nitric acid, malic and oxalic acids are ultimately, but slowly, produced.

The fixed alkalis exert a remarkable action upon these oils, which terminates in the formation of *soap*, and a similar change is effected, though more slowly, by ammonia: these combinations we shall presently revert to. There are many other metallic oxides which appear to act more or less upon the oils in the manner of the alkalis. Sulphuret of carbon, some of the hydrocarbons, and a few of the metallic chlorides also dissolve in the fixed oils; there are, however, but few of the salts which are soluble in them to any extent.

The ultimate composition of the fixed oils has been accurately ascertained, but there are two difficulties in the way of determining their equivalents: the one is, that their absolute purity is difficultly ensured, and the other, that they do not combine with bases without undergoing change. The following are a few of the results of these analyses:

	Olive Oil. Gay Lussac and Thenard.	*Linseed Oil.* Saussure.	*Castor Oil.* Ure.	*Stearin of Olive Oil.* Saussure.	*Elain of Olive Oil.* Saussure.
Carbon	77.213	76.014	74.00	82.17	76.03
Hydrogen	13.360	11.351	10.29	11.23	11.54
Oxygen	9.427	12.635	15.71	6.30	12.07
	100.000	100.000	100.00	99.70	99.64

Saussure ascribes the loss in his analyses to nitrogen: he infers also, from the comparative analysis of stearin and elain, and from other results which I shall afterwards quote, that those oils which are most easily solidified, are those which contain the least oxygen, and that they are also the least soluble in alcohol.

The fixed oils are extremely numerous, and many of them have been examined and described: the following are a few details respecting their principal varieties, abridged chiefly from L. Gmelin and Berzelius.

1. Drying Oils. Linseed Oil is expressed from the seeds of common flax (*Linum usitatissimum.*) Cold-drawn, it is greenish-yellow and more viscid than when hot-drawn. Its specific gravity varies between 0.928 and 0.932. It dissolves in 5 parts of boiling alcohol, 40 of cold, and 1.6 of ether. A preparation of linseed oil, called *drying oil* or *painters' varnish*, is made by mixing a quart of the oil with about half an ounce of powdered litharge, and a quarter of an ounce of white vitriol, in a glazed pipkin, and heating it over a gentle fire so as to keep it for 4 or 5 hours simmering; the lower the heat, and the longer it is continued, the better is the varnish. In this process, the greater part of the oxide of lead is reduced. This, and other drying oils, and especially *nut oil*, form the basis of *printers' ink*, the history of which will be found in Lewis's *Phil. Commerce of the Arts.* The oil is heated and set fire to, and, after having been suffered to burn for half an hour, is extinguished, and boiled till it acquires a due consistency; in this state it is called *Varnish*, and is viscid, tenacious, and easily miscible with fresh oil, or with oil of turpentine, by which it is properly thinned, and afterwards mixed with about one-eighth part of lamp-black.

For white paint and light colours, unboiled linseed oil is used: it dries slowly, but does not injure the colour. There is a mixture of drying oil and mastic varnish, known to artists by the term *magilp*, of a gelatinous consistence, and an excellent vehicle for colours.

Walnut Oil, expressed from the seeds of the walnut-tree, (*Juglans regia,*) has a specific gravity of about .920 at 60°; it is inodorous, and as it dries better than linseed oil, is sometimes preferred by painters.

Hemp Oil, from hempseed, (*Cannabis sativa,*) has an unpleasant odour, dissolves in all proportions of boiling absolute alcohol, but requires 30 parts of cold alcohol. It is much used in some parts of the North of Europe to burn, and for paints.

Poppy Oil expressed from poppy-seed, (*Papaver somniferum,*) is bland and insipid. Its specific gravity = .924. It dissolves in 25 of cold and 6 of boiling alcohol, and is used in some parts of Germany and France as a substitute for olive oil.

Castor Oil is the produce of the seeds of the *Ricinus communis.* It is pale-yellow: its specific gravity at 55° is .969, at 75° = .957, at 212° = .908. (Saussure.) It has a slightly nauseous odour and taste: it differs, however, much in these respects, and that which is at present used in medicine, and which is *cold-drawn* by pressure, is less acrid and purgative than the West India castor oil, formerly preferred for medical use, and which was often pressed with heat, or even boiled out of the seeds*. It congeals at about 0°. Exposed to air it gradually becomes rancid, thick, and at length congeals. It dissolves (in all proportions?) in absolute alcohol and in ether, by which foreign substances are occasionally separated from it. The products of the distillation of this oil have been examined by Bussy and Lecanu (*Journal de Pharm.*, xiii., 68); they obtained from them a peculiar acid (*ricinic acid*), forming with magnesia and oxide of lead, salts soluble in alcohol, and resembling one of its products of saponification.

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* Guibourt ascribes the medicinal activity of castor oil to a peculiar volatile principle, which he says is expelled by heat, and considers the purgative power of the cold-drawn oil to exceed that of the oil obtained by aid of heat.

Croton Oil. This, which is the expressed oil of the seeds of the *Croton tiglium*, is used in medicine as a drastic purge. It has a brown or yellow colour, an acrid taste, and is operative in doses not exceeding a single drop: the oil, however, as met with in commerce, varies much in activity. When the seeds are digested in ether we obtain, according to Nimmo, 60 *per cent.* of their weight of oil, of which two-thirds are soluble in alcohol and purgative; one-third is bland and inert. The acrid principle of the croton-seed appears to be *acid*, and has been termed, by Pelletier and Caventou, *Iatrophic Acid*, from erroneously supposing the seeds to be the produce of the *Iatropha curcas*. Brandes has since examined the acid, and calls it *Crotonic Acid*.

2. Greasy Oils. Almond Oil is expressed from sweet and bitter almonds: it is pale-yellow, and becomes colourless when long exposed to light: it soon grows rancid, especially if in contact of oxygen. Its specific gravity at 60° is .91 to .92. When cooled down to 15° it yields 0.24 margarin, and 0.76 elain: the latter does not congeal at 0°. Almond oil is soluble in 25 parts of cold and 6 of boiling alcohol: it readily dissolves in ether.

Olive Oil is extracted from the fleshy part of the olive (the fruit of the *Olea europæa*). It is pale-yellow, and its specific gravity is about .910 at 60°. When cooled down to 0° and expressed, it yields about 0.28 margarin, and 0.72 elain: it often deposits margarin at common temperatures, a portion of which is generally found at the bottom of the jars and casks in which it is kept. The quality of this oil is very various: the best is obtained by gentle pressure without heat; that which is procured by the aid of heat, and of a greater degree of pressure, is called *second oil;* and a very inferior kind is ultimately extracted by boiling the expressed cakes in water. Fine olive oil is extremely bland and tasteless, or at least has only a slight nutty flavour: the commoner kinds, (that, for instance, called *Gallipoli oil*,) are disagreeable both in smell and taste. Olive oil is sometimes adulterated with the cheaper expressed oils, especially with rape and poppy oil.

If pernitrate of mercury, made by dissolving 6 parts of mercury in 7.5 parts of nitric acid of specific gravity 1.36, at common temperature, be mixed with olive oil, in the course of a few hours, the mixture, if kept cold, becomes solid; but if mixed with the oil of grains, it does not solidify. Poutet (*Ann. de Chim. et Phys.*, xii., 58) has, therefore, proposed this as a test of the purity of olive oil; for the resulting mixture, after standing twelve hours, is more or less solid, as the oil is more or less pure. The nature of the compound formed by olive oil and the nitrate of mercury, has been examined by M. F. Boudet (*Ann. de Chim. et Phys.*, l., 391). I shall afterwards revert to it.

Rousseau states that olive oil is the worst conductor of electricity of all the fat oils, and suggests a mode of applying this test to the detection of its adulterations.

Of all the oils, that of olives is least apt to become viscid and glutinous, and hence is preferred for greasing delicate machinery, as especially watch and clock-work. For this purpose the elain may perhaps be preferable to the entire oil. Watchmakers are in the habit of preparing the oil for this purpose, by keeping a piece of sheet-lead, or some shot in it, and exposing it in a corked bottle to light. A white matter is gradually deposited, and the oil ultimately becomes clear and colourless, and no longer affected by the metal: this subject has not been scientifically investigated.

Beech-nut Oil. The decorticated nuts of the beech-tree (beech-mast) yield about 15 *per cent.* of oil resembling olive oil, and a larger quantity when aided by heat; the remaining cake is a better food for cattle than common oil-cake.

Oil of Ben is procured by expression from the decorticated seeds of the *Guilandia moringa*, a tree which grows in Ceylon, Ethiopia, Egypt, and Arabia. The oil is perfectly inodorous, and does not readily grow rancid, hence its excellence for the preparation of certain *scented oils*, such as those of the jasmine, tuberose, &c.

Rape Oil is expressed from the seeds of the *Brassica napus*, and *rapa.* Its specific gravity at 60° is .912. This, and some other of the fat oils, contains a principle in solution, which interferes with its combustibility, and which may be abstracted by agitating the oil with about 2 *per cent.* of sulphuric acid, and afterwards washing it with 2 or 3 parts of water, with which it is left for two or three weeks, at a temperature between 75° and 80°: it gradually forms a deposit, from which it is drawn off, and filtered, and is then fit for burning in lamps. *Colsa* or *cole-seed oil* is a better kind of rape oil, extracted from the *Brassica campestris*, var. *oleifera.*

Mustard-seed Oil is expressed from the seed of the *Sinapis alba* and *nigra:* the bruised seed yields about one-fifth its weight of a mild, inodorous, thick, amber-coloured oil: specific gravity .915 at 60°, soluble in 1000 parts of alcohol (specific gravity .833), and in 4 of ether. Alcohol extracts from it a peculiar acid (the *sulphosinapic**), and a crystallizable fatty matter, which is not saponifiable.

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* *Sulphosinapic acid* was found by Henry and Garot (*Jour. de Chim. Med.* 1.) in mustard, radish, and turnip-seed, and in the root of the horse-radish. 3 parts of expressed mustard oil and 4 of strong alcohol were mixed and often shaken together. After 3 days the yellow alcohol was poured off, and two-thirds abstracted by distillation: on cooling, the residue deposited the fatty matter above-mentioned, and the remaining liquid was decanted off, and left to spontaneous evaporation: it now deposited a granular mass, which by continuous digestion in ether, yields to that solvent a red fat, and the remaining matter (insoluble in ether) was dissolved in water, and left to spontaneous evaporation: scattered crystals were thus obtained, of a yellow colour, bitter pungent taste, and sulphurous odour. The composition of these crystals of *Sulphosinapic acid* is remarkable, as essentially including five elementary substances, namely,

Sulphur . . .	17.33
Carbon . . .	49.50
Hydrogen . .	8.30
Oxygen . . .	11.91
Nitrogen . . .	12.96
	100.00

Berzelius has thrown out the suggestion that this acid may be a compound of hyposulphurous acid, and an organic base. The *Sulphosinapates* of the alkaline bases are crystallizable, but the equivalent of the acid has not been satisfactorily determined. It yields precipitates in the solutions of acetate of lead, protonitrate of mercury, nitrate of silver, and sulphate of copper.

3. CONCRETE OILS. VEGETABLE BUTTERS. The principal oils of this class are the following.

COCOA-NUT OIL, pressed, or boiled, out of the nut of the *Theobroma cacao.* When washed it is white, of a peculiar odour, and of the consistence of tallow: its specific gravity = .910. It fuses at about 125°. Its *elain* is used as a *lamp oil*, and its *stearin* or *margarin* for the manufacture candles.

PALM OIL. Many of the palms produce a hard nut, like the datestone, but abounding in oil: of these the principal are the *Cocus butyracea* and *Elæis guineensis.* These oils are used for soap, candles, &c., and the stearine and elain employed as the preceding.

NUTMEG OIL is the expressed oil of the common nutmeg; it is yellow, and smells of the essential oil. It is largely prepared in Holland, and occasionally used in medicine. According to Schrader, 16 ounces of the concrete expressed oil of nutmeg contain 7 of hard concrete oil, 8⅓ yellow butyraceous oil, and ⅔ volatile oil. Cold alcohol dissolves the volatile and the soft oil, and leaves the harder oil. When nutmeg oil is boiled in four parts of alcohol, it is entirely dissolved, and the harder fatty portion is deposited as the solution cools. Marrow, or common fat, scented by a little oil and powder of nutmeg, and coloured by annotto, is sometimes substituted for this oil: the fraud is detected by the insolubility of this artificial mixture in 4 parts of boiling alcohol. (Bollaert, *Quarterly Journal*, xviii., 317.)

WAX. This principle exists in many plants; it may be obtained by bruising and boiling them in water: the wax separates and concretes on cooling. The berries of the *Myrica cerifera*, and the leaves and stem of the *Ceroxylon*, afford considerable quantities of wax by this process. (Bostock, Nicholson's *Journal*, vol. iv., Brande, *Phil. Trans.*, 1811.) The glossy varnish upon the upper surface of the leaves of many trees is of a similar nature; and though there are shades of difference, these varieties of wax possess the essential properties of that formed by the bee; indeed, it was formerly supposed that bees merely collected the wax already formed by the vegetable, but Huber's experiments show that the insect has the power of transmuting sugar into wax, and that it is in fact a secretion.

BEES'-WAX. White wax, or bleached bees'-wax* is colourless and insipid; its specific gravity is about .96: it is insoluble in water, and fusible at a temperature of about 150°; at a higher temperature it is converted into vapour, and may be distilled with little other change than the production of a small portion of stearic acid, and at a red-heat it burns in the contact of air with a bright flame. It is sparingly soluble in boiling alcohol and ether, and is deposited as the solutions cool. Twenty parts of boiling alcohol dissolve about one of bees'-wax, of which not more than one-fifth is retained at the temperature of 60°, and this is thrown down by the addition of water. Cold ether appears without action on wax, but boiling ether takes up about one-tenth of its weight, and deposits nearly the whole on cooling. The fixed oils, when assisted by heat, readily dissolve it, and form a compound of variable consistency, which is the basis of *cerates* and *ointments*. Some of the volatile oils also dissolve wax, when aided by heat. It combines with the fixed alkalis, forming imperfect soapy compounds of very difficult solubility, and from which the acids separate the wax in an unaltered state. The acids, at common temperatures, scarcely act upon wax; hence the advantage of *wax-lute* for the retention of corrosive vapours. At the fusing-point of wax it combines with sulphuric acid, and the solution congeals on cooling. Muriatic acid has no action upon it; nitric acid, after long boiling, very slowly converts a portion of it into oxalic acid.

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* The bleaching of bees'-wax is effected by exposing it in thin ribands upon the bleaching-ground. It may be whitened by chlorine, but wax so bleached never burns well; it smells of, and appears to contain, chlorine.

Myricin. When myrtle-wax is digested in boiling alcohol, it affords, according to Dr. John, a soluble and insoluble portion; he has called the former *cerin*, the latter *myricin*. Cerin is insoluble in water and in cold alcohol and ether, but dissolves in those liquids when heated. Myricin is insoluble, under all circumstances, in alcohol and ether.

Cerine. This term has been applied by Chevreul to a principle resembling wax, which he separated from *cork*; it is less fusible than wax, more soluble in alcohol, and partly converted into oxalic acid, by the action of nitric acid.

Bees'-wax has been analyzed by Gay-Lussac and by Dr. Ure, with the following results:—

	Gay Lussac.	Ure.
Carbon	81.784	80.60
Hydrogen	12.672	11.47
Oxygen	5.544	7.93
	100.00	100.00

According to Oppermann, pure vegetable-wax differs slightly from bees'-wax, in the ratio of its elements.

§ XII. Soaps. Saponic, or Adipose Acids.

Process of Saponification. When the fat oils are digested with caustic alkali, a compound results, long and well known under the name of *soap;* with the real nature however of this compound we were not acquainted, till the subject was investigated by Chevreul, who, in the masterly researches already quoted (see also *Recherches Chimiques sur les Corps gras.* Paris 1823,) demonstrated the nature of the changes which the oils undergo, and discovered a number of new acid substances into which they are converted. These experiments have principally reference to *animal oils*, and the general account of them ought strictly to be referred to the chemical history of animal products: but the *vegetable* oils and fats are in many of their properties identified with, and in all so closely analogous to the corresponding products of animals, that I shall give an abstract of the whole subject in this place.

The various kinds of *soaps* differ chiefly in the oil or fat used in their manufacture, for the alkali which is employed is, for *hard soaps*, almost invariably soda: by the mutual action of the oil and alkali the stearic and elaic components of the former are converted into one or more *acids*, which combine with the soda, so that in this respect, soaps may be correctly spoken of, as a class of *salts*, deriving their peculiarities almost exclusively from the *acids* which they contain. The soap of olive oil and soda may be taken as a specimen of this article: it is made as follows. Five parts of barilla, or an equivalent proportion of other carbonate of soda, are mixed with one of lime, and a proper quantity of water. In this way a *ley*, or solution of *caustic soda*, is obtained, which is boiled in an iron pot with *six parts* of the oil, till the *soap* separates: this separation of the soap from the water, is accelerated by the addition of common salt; it is then suffered more perfectly to congeal, and in a few days becomes hard enough to cut into forms. (AIKIN'S *Dictionary*—Art. SOAP.) The best soaps are made with olive oil and soda; in this country *animal fat* is usually employed for the common soaps, to which resin and other substances are occasionally added. *Soft Soap* is made with potassa and some of the common oils; even fish oil is often used, and hence peculiar compounds or *salts* result, as we shall presently find*.

The general properties of soap are the following. It furnishes a milky solution with water. It dissolves in alcohol, and the solution, if concentrated, is of a gelatinous consistency, and by carefully distilling off the alcohol, a *transparent soap* is obtained. The acids, and the greater number of salts, decompose soap, forming, in most cases, a compound of difficult solubility; hence, *hard waters* are unfit for washing, in consequence of containing sulphate of lime; hence, also, the *alcoholic solution of soap* is useful as a test for ascertaining the fitness of water for this purpose, which, if it becomes very turbid, cannot in general be used for washing.

When the above soap is decomposed by dilute sulphuric acid, sulphate of soda is formed, but the oil is not separated in its former state, but has acquired the new properties we are about to notice: there is also formed during the mutual action of the oil and alkali, a compound discovered by Scheele, and called by him the *sweet principle:* it has since been termed *glycerine*, (from γλυκυς, *sweet.*)

GLYCERINE may be obtained by saturating the alkaline mother-liquor, from which the soap has concreted, by dilute sulphuric acid, adding a little carbonate of baryta to remove any slight excess of the acid, filtering, and evaporating to the consistency of thin syrup, to which alcohol is then added, which dissolves the *glycerine* and leaves the alkaline sulphate. Glycerine is not crystallizable; it has a pure sweet flavour, and cannot be deprived of water without decomposition. When distilled, a portion passes over unaltered. Heated in the air it burns with a blue flame. It is very difficult of conversion into oxalic acid by the action of nitric acid, and has very little tendency to fermentation.

When glycerine is obtained by evaporating its alcoholic solution in vacuo, it is in the state of *hydrate*. Dumas represents its ultimate components as follows†.

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* The fixed oils also form peculiar compounds with, or are *saponified*, by *hydrated oxide of lead*, when aided by heat, forming the substance usually termed *plaster;* with the oxides of mercury and bismuth they produce very similar combinations.

† (See Fremy, *Ann de Chim.* lxiii. 25. Vogel, *Journal de Pharm.* iv. 255, and Chevreul, *Recherches.*)

				Dumas.
Carbon	3	18	48.7	49.20
Hydrogen	3	3	8.1	8.00
Oxygen	2	16	43.2	42.80
	1	37	100.0	100.00

And, as containing in the state of *hydrate* 1 atom of water (37+9 =46), or

Anhydrous glycerine $= (3\,car + 3\,h + 2\,o.)$
Hydrated do. $= (3\,car + 4\,h + 3\,o.)$

Having thus stated the general results of saponification, I shall give an outline of the properties of the *acids* generated by the action of the alkalis, and of such other analogous bodies as are included by Dumas under the term *Adipose acids.* (*Acides gras*, see *Traité de Ch. App. aux Arts.* v. 239.)

Adipose Acids; Saponic Acids. These substances, when *solid*, resemble fat, wax, or spermaceti; when *liquid*, they look like thin oils. They are mostly fusible at temperatures below 212°; they are more or less volatile, colourless when pure, lighter than water, soluble in alcohol and ether, and in the fixed and volatile oils. They contain much less oxygen than is requisite to convert their carbon and hydrogen into carbonic acid and water, and hence are eminently inflammable. They are little affected by air or by acids at common temperatures: heated with sulphuric or nitric acid they are decomposed: they redden litmus. Their equivalent is always a high number. Aided by heat they decompose the carbonates.

The greater number of these acids are not found in a separate state, but they appear to exist in oils and fats in union with an organic base. They are divided by Dumas into, 1. Those which are insoluble in water, and which only admit of distillation in vacuo: 2. Those which are soluble in water, and which may be distilled over with water in the ordinary way.

I. Stearic Acid. This acid is the most characteristic product of the saponification of suet, and other hard or not easily-fusible fats. It is obtained by decomposing *stearate of potassa*, by dilute muriatic acid. It melts at 158° and concretes into a mass of shining crystals. Boiling anhydrous alcohol dissolves it in all proportions, and the solution yields nacreous crystals: it is soluble in its weight of ether: it is volatile in vacuo: it burns in the air like wax. It is soluble in cold sulphuric acid, and decomposed by it when heated: it is not acted on by cold nitric acid, but the boiling acid dissolves and modifies it. This acid consists of*

				Chevreul.
Carbon	35	210	79.55	80.145
Hydrogen	33	33	12.88	12.478
Oxygen	2½	20	7.57	7.377
Anhydrous stearic acid	1	263	100.00	100.000

The *hydrated stearic acid* consists of 1 atom anhydrous acid and 1 of water (264 + 9 = 273), or

Anhydrous stearic acid $(35\,car + 34\,h + 2\tfrac{1}{2}\,o.)$
Hydrated do. $(35\,car + 35\,h + 3\tfrac{1}{2}\,o.)$

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* The atomic composition of stearic acid, as given by Dumas, is $(70\,car + 78\,h + 5\,o)$, which would produce the equivalent 527, or double that *in the text*, assuming 33½ instead of 34 atoms of hydrogen.

Stearate of Ammonia. Stearic acid absorbs gaseous ammonia, and forms a white inodorous compound, of an alkaline taste. It dissolves in boiling water, and the solution deposits nacreous crystals of *bistearate*.

Stearate of Potassa is formed by boiling 1 part of stearic acid and 1 of caustic potassa in 10 of water: it falls in white opaque grains, which may be purified by solution in 15 to 20 parts of boiling alcohol: it falls, as this solution cools, in brilliant scales. Stearate of potassa may also be obtained by treating the soap of potassa with alcohol. This soap is prepared by boiling 100 parts of mutton-suet and 25 of caustic potassa in 100 of water, agitating the mixture till a homogenous compound is obtained: it is a mixture of *stearate*, *oleate*, and *margarate of potassa:* the two last are abstracted and retained by warm alcohol, which deposits the stearate. It consists of

				Chevreul.
Potassa	1	48	15.4	15.29
Stearic acid	1	263	84.6	84.71
	1	311	100.0	100.00

Bistearate of Potassa. 1 part of the above soap is dissolved by heat in 6 of water, and then 50 or 60 parts of cold water are added to the solution: a nacreous substance is deposited, composed of bistearate and bimargarate of potassa: this is dissolved in 20 to 24 parts of boiling alcohol (specific gravity 0.82), and during cooling, crystals are deposited, which, when dissolved in alcohol a second time, and again crystallized, are *bistearate of potassa.* It forms soft silvery scales, infusible at 212°, insoluble in cold water, but resolved by boiling water into potassa and *quadristearate.* It is soluble in boiling alcohol, 100 parts of which take up 27 of bistearate of potassa, but only retain 0.36 at 75°. The crystallized bistearate of potassa consists of

				Chevreul.
Potassa	1	48	8.2	8.075
Stearic acid	2	526	90.3	9.075
Water	1	9	1.5	1.850
	1	583	100.0	100.000

Stearate of Soda. The action of soda on stearic acid resembles that of potassa; and a stearate and bistearate, corresponding in composition with the above, are produced, but they are less soluble than the salts of potassa.

Stearate of Lime is a white, fusible, tasteless powder, thrown down when a boiling solution of neutral stearate of potassa is added to a solution of chloride of calcium. It consists of

				Chevreul.
Lime	1	28	9.7	9.96
Stearic acid	1	263	90.3	90.04
	1	291	100.0	100.00

Stearate of Baryta is formed by mixing hot solution of stearate of potassa with nitrate of baryta: it is a white, fusible, insipid powder. It contains

				Chevreul.
Baryta	1	77	22.5	22.31
Stearic acid	1	263	77.5	77.69
	1	340	100.0	100.00

STEARATE OF LEAD is white, fusible, and insoluble in water: it is formed by the action of a boiling solution of stearate of potassa on nitrate of lead. It consists of

				Chevreul:
Oxide of lead	1	112	29.79	29.5
Stearic acid	1	263	70.21	70.5
	1	375	100.00	100.0

STEARONE. When stearic acid is distilled with a fourth-part of quicklime, a substance is obtained sparingly soluble in ether and alcohol, concrete at common temperatures, but fusible at about 180°. (Bussy, *Jour. de Phar.*, xix., 643.) It consists of

Carbon	68	408	85.4
Hydrogen	62	62	12.9
Oxygen	1	8	1.7
	1	478	100.0

STEARINE. The origin of this term and the substance to which it is applied, derived from olive-oil, have been already noticed. The purest form of *Stearine* is procured by digesting purified mutton suet in cold ether, as long as it dissolves any part of it: the residue, dried by pressure between folds of blotting-paper, is of a crystalline texture, semitransparent, friable, and fusible at about 110°. It is not soluble in cold alcohol, hence, when dissolved in boiling alcohol, it is deposited on cooling. It is only very sparingly soluble in cold ether; more so in boiling ether. A hot and concentrated solution of caustic potassa dissolves and saponifies it, forming a compound soluble in cold alcohol, and in water: this solution, decomposed by diluted muriatic acid, yields a precipitate of pure stearic acid, and glycerine is found in the residuary mother-liquor. 100 parts of stearine yield 96.8 stearic acid and 8 glycerine. Stearine is a compound of

			Dumas.
Carbon	73	438	78.02
Hydrogen	69	69	12.20
Oxygen	7	56	9.78
	1	563	100.00

and these numbers are equivalent to 1 atom of anhydrous *stearic acid* + 1 of anhydrous *glycerine;* or

Stearic acid = (70 *car* + 66 *h* + 5 *o*)
Glycerine = (3 *car* + 3 *h* + 2 *o*)
Stearine = (73 *car* + 69 *h* + 7 *o*)

So that upon this view stearine is a *stearate of glycerine;* the glycerine being the organic base.

II. MARGARIC ACID, so named from its pearly lustre (μαργαριτη, *a pearl,*) bears a striking resemblance to stearic acid. It is obtained by decomposing the *margarate of potassa*, or *margarate of lead*, by hot and very dilute muriatic acid: it fuses at 140°, and in respect to fusibility and solubility, is intermediate between stearic and oleic acids. It is composed, in its *anhydrous* state, of

			Chevreul.	Berzelius.
Carbon	35	210	79.053	78.38
Hydrogen	33	33	12.010	12.59
Oxygen	3	24	8.937	9.03
	1	267	100.000	100.00

I have adopted the atomic composition suggested by Berzelius*, because it refers to the purest form of margaric acid, and represents it as an oxide of the same base (or hydrocarbon,) as the stearic acid. This view was originally adopted by Chevreul, who then applied to it the name of *margarous acid.*

MARGARATE OF AMMONIA is formed as the corresponding *stearate.*

MARGARATE OF POTASSA. This salt may be obtained from the *soap of olive-oil*, from which alcohol, very moderately heated (at 70 or 80°), abstracts the *oleate*, and leaves the *margarate of potassa.* (See *Margarine.*) Chevreul procured it from human, and from goose-fat, saponified by potassa. It is softer, more fusible, and more soluble in alcohol than the stearate of potassa. It consists of

			Chevreul.
Potassa	1	48	15
Margaric acid	1	267	85
	1	315	100

BIMARGARATE OF POTASSA may be obtained as the *bistearate;* it crystallizes with 1 atom of water. Its hot aqueous solution, when decomposed by dilute muriatic acid, yields a precipitate of margaric acid.

MARGARATE OF SODA closely resembles the salt of potassa. The neutral margarate is soluble in 10 parts of water, at 175°.

MARGARATE OF LEAD. With oxide of lead, the margaric acid forms a neutral, a basic, and an acid salt. A mixture of margarate and oleate of lead (as obtained by double decomposition, from a soap of olive-oil) may be separated by cold ether, which leaves the margarate, but dissolves the oleate.

MARGARONE. A substance under this name is described by Bussy, (*Jour. de Phar.*, xix., 635.) among the products of the destructive distillation of a mixture of margaric acid with one-fourth its weight of lime. It is said somewhat to resemble *paraffine*, and to consist of $(68\,car + 67\,h + 2\,o)$ numbers which are equivalent to hydrocarbon $(67\,car + 67\,h)$ and carbonic acid $(car + 2\,o)$. Its theoretical relations to paraffine and to margaric acid, are pointed out by Dumas.

MARGARINE. This substance forms a part of mutton-suet, hogs'-lard, and some other animal fats: it appears to form the greater portion of the concrete part of olive oil, already mentioned, and when that substance is dried in bibulous paper, dissolved in ether, and left to spontaneous evaporation, the white flakes which are deposited are *margarine.*

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* Chevreul gives $(70\,car + 65\,h + 6\,o) = 533$. Gmelin represents margaric acid by the equivalent 266, or $35\,car + 32\,h + 3\,o)$, or 64 instead of 65 atoms of hydrogen, if doubled.

Margarine is distinguished from stearine by its greater fusibility. It is so far soluble in cold ether, that at 65°, two parts are retained in permanent solution by five of ether. A solution of two parts of margarine in 10 of ether, is permanent at 60°, and does not begin to deposit till cooled down to 54°. The atomic constitution of margarine has not been accurately determined.

III. **Oleic Acid.** This acid is obtained by the decomposition of *oleate of lead*, or *oleate of potassa*, by a solution of tartaric acid: it separates in the form of an oil, and is to be washed with hot water: it often contains margaric acid, which it deposits by cautious cooling: when pure, it remains transparent at 32°. It resembles a colourless oil, of a slightly rancid taste and smell; its specific gravity is 0.898 at 65°. A few degrees below 32°, it concretes into a white acicularly-crystalline mass; it is not soluble in water, but is taken up in all proportions by alcohol of the specific gravity .822. It reddens litmus; mixes readily with stearic and margaric acids, and behaves like them when subjected to distillation. According to Chevreul, *anhydrous* oleic acid may be regarded as a compound of

				Chevreul.
Carbon	35	210	81.08	80.942
Hydrogen	30	29	11.20	11.359
Oxygen	2½	20	7.72	7.699
	1	259	100.00	100.000

The *crystallized acid* includes 1 atom of water.

Oleate of Ammonia. Liquid ammonia rapidly dissolves oleic acid; heat is evolved, and a gelatinous mass, soluble in water, is formed.

Oleate of Potassa. This salt may be best extracted from the *soap of linseed oil*, which is dried, and digested in cold anhydrous alcohol; the clear solution is evaporated, and the residue again treated by cold anhydrous alcohol, by which any trace of margarate of potassa is left undissolved. The solution now contains pure *oleate of potassa*, and when slowly evaporated yields it, sometimes in an imperfectly-crystallized mass: its taste is alkaline and bitter: mixed with 2 parts of water it forms a transparent jelly: with 4 of water the solution is viscid: it absorbs moisture from the air. In the voltaic circuit it yields oleic acid at the positive, and potassa at the negative pole. At 122° alcohol dissolves its own weight of this salt, and the compound gelatinizes on cooling. Chevreul has also described a *binoleate*.

The *anhydrous* oleate of potassa consists of

			Chevreul.
Potassa	1	48	15.19
Oleic acid	1	259	84.81
	1	307	100.00

Oleate of Soda is an easily-soluble salt.

Oleate of Baryta is insipid, insoluble in water, very sparingly soluble in boiling alcohol, and soluble in oleic acid.

Oleate of Copper is green, and easily fusible.

Oleate of Lead is liquid at 77°, and viscid at lower temperatures: it is soluble in alcohol and ether.

Oleone is a liquid product obtained by distilling oleic acid with lime.

Elaïdine. M. Poutet's test of the purity of olive oil has been above adverted to. (p. 955.) The action of *nitrous acid* upon oil has been examined by M. Felix Boudet, (*Ann. de Chim. et Phys.*, L., 391,) he finds that when *olive* oil is shaken with a mixture of 3 *per cent.* of nitrous, and 9 of nitric acid, it solidifies in the course of an hour: that linseed oil, nut oil, poppy oil, hempseed oil, and beech-mast oil, are not so solidified: almond oil, and rape oil, are more slowly but similarly changed. *Castor oil* is also solidified, but the product is distinct*. M. Boudet applies the term *Elaïdine* to the above product; and when saponified by potassa, it yields a peculiar fat acid, which he calls *Elaïdic acid* †.

§ XIII. Volatile Oils. Camphene. Camphor. Camphoric Acid. Citrene. Oil of Copivi.

The *volatile* or *essential oils* are generally obtained by distilling the vegetables, or the parts of the plants which afford them, with water, in common stills; the water and oil pass over together, and are collected in the *Italian recipient* shown in the following cut, in which the water, having reached the level *a b*, runs off by the pipe *c*, and the oil, being generally lighter than water, floats upon its surface in the space *d*. The whole contents of the recipient are then poured into a funnel, the tube of which is closed with the finger; and when the oil has collected upon the surface, the water is suffered to run from it, and the oil transferred into a bottle. The distilled water, being saturated with the oil, should be retained for a repetition of the distillation. The produce of oil is sometimes increased, by adding salt to the water in the still, so as to elevate its boiling-point a few degrees.

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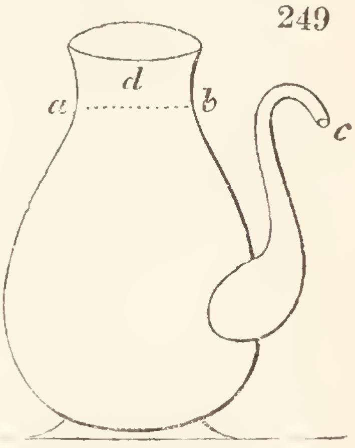

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* Bussy and Lecanu, (*Jour. de Phar.*, xiii.,) have elaborately examined the products of castor oil, and have obtained from it, as results of saponification, *margaritic*, (not *margaric*,) *ricinic*, and *elaiodic* (not the *elaïdic* acid of Boudet) acids. When castor oil is solidified by hyponitrous acid, (or by nitrate of mercury?) it yields a substance distinct from elaïdine, called by Boudet, *palmine*. When palmine is saponified, and the soap decomposed by an acid, *palmic acid* is separated.

† *Rocellic*, *valerianic*, and *esculic* acids, are placed by Dumas among the fat acids. *Rocellic acid* was discovered by Heeren, in the *rocella tinctoria*: he obtained it by digesting the lichen in liquid ammonia, precipitating by chloride of calcium, and decomposing the *rocellate of lime* by muriatic acid, when rocellic acid subsides: it is washed, and purified by solution in ether, which afterwards deposits it in silky crystals, fusible at 265°: soluble in twice their weight of boiling alcohol, and composed, according to Liebig, of (16 *car* + 16 *h* + 4 *o*). The *rocellates* are analogous to soaps.

Valerianic or *valeric acid*, passes over with essential oil when the root of the *Valeriana officinalis* is distilled with water: the product is mixed with carbonate of magnesia and water, and distilled: the oil passes over, and *valerianate of magnesia* remains: to this, dilute sulphuric acid is added, by which it is decomposed, and the valerianic acid may now be obtained by distillation, partly floating upon the water, and partly dissolved in it. It is a colourless oily liquid, smelling strong of valerian, specific gravity 0.94, acrid and acid to the taste, soluble in 30

Some of the volatile oils are obtained by expression, such as those of *lemon*, *orange*, and *bergamot*, which are contained in distinct vesicles in the rind of those fruits.

The volatile oils vary considerably in specific gravity, as shown by the following Table:—

Oil of Sassafras	1.094	Oil of Tansy	946
„ Cinnamon	1.035	„ Caraway	940
„ Cloves	1.034	„ Origanum	940
„ Fennel	997	„ Spike	936
„ Dill	994	„ Rosemary	934
„ Pennyroyal	978	„ Juniper	911
„ Cummin	975	„ Oranges	888
„ Mint	975	„ Turpentine	872
„ Nutmegs	948		

The *general* characters of these oils are the following: they have a penetrating odour and taste, and are generally of a yellowish colour; they are for the most part very soluble in alcohol, and very sparingly soluble in water; these solutions constitute *perfumed essences* and *distilled waters*. The latter are principally employed in pharmacy, and the former as perfumes. When pure, they pass into vapour at a temperature somewhat above that of 212°, but when distilled with water, they pass over at its boiling-point. They are very inflammable, and water and carbonic acid are the results of their perfect combustion. As many of these oils bear a very high price, they are not unfrequently adulterated with alcohol and fixed oils. The former addition is rendered evident by the action of water; the latter, by the greasy spot which they leave on paper, and which does not evaporate when gently heated. By long keeping, some of the essential oils are concreted into a substance resembling spermaceti; this is especially the case with the ottar of rose, and sometimes appears connected with the destruction of its odoriferous principle. When oil of aniseed is kept for many years it also loses its odour, and becomes entirely solid. Other oils become resinous by age. (MAC CULLOCH, *Quarterly Journal*, *N. S.*, v., 291.) The volatile oils absorb oxygen, when long exposed to it, and become thick and resinous. Nitric and sulphuric acids rapidly decompose the volatile oils: a mixture of four parts of nitric, and one of sulphuric acid, poured into a small quantity of oil of turpentine, produces instant inflammation. They absorb chlorine, and muriatic acid is produced, along with a peculiar substance, called artificial camphor. Iodine produces changes somewhat analogous. Muriatic acid combines with several of them, and forms a crystallizable compound which has also been compared to camphor.

The relative quantity of essential oils, furnished from different

---

parts of water, and in all proportions of alcohol. According to Essling, as quoted by Dumas, this acid in its oily form is a *hydrate*, composed of $(10\,car+10\,h+4\,o)$, the *anhydrous* acid being represented by the equivalent $=(10\,car+9\,h+3\,o)$.

Esculic acid was obtained by Fremy, by digesting pulverized horse-chestnuts in alcohol: the solution left, on evaporation, a peculiar yellow viscous matter, probably identical with the *saponin*, obtained by Bussy, (*Jour. de Phar.*, xix.,) from the root of the Egyptian *Saponaria*, (*Gypsophila struthium?*) This matter, when digested with solution of potassa, yields a soapy compound, from which the acids separate *esculic acid*. Such details respecting its nature and properties as have been ascertained, are given by Dumas (*Chim. ap. Aux Arts.*, v., 296).

materials, is liable to much variation; the following are the average products of 1 cwt. of the different vegetable substances:—

	Ounces.		
Juniper-berries (common)	4	to	5
,, ,, (fine Italian)	7	,,	8
Aniseed (common)	32	,,	36
,, (finest)	36	,,	38

		lbs	oz.		lbs.	oz.
Caraways	from	3	12	to	4	12
Dill-seed	,,	2	0	,,	2	6
Cloves	,,	18	0	,,	20	0
Pimento	,,	2	0	,,	3	4
Fennel-seed	,,				2	0
Leaves of the *Juniperus sabina*					0	14

The essential oils have recently been subjects of more interest to the chemist, from the results afforded by their ultimate analysis: these have shown that certain organic compounds, commonly arranged with the volatile oils are binary compounds of carbon and hydrogen, or *hydrocarbons:* to these, allusion has already been made (p. 481), and we shall now have to consider them more in detail: others are ternary compounds of carbon, hydrogen, and oxygen, or *oxides of hydrocarbon*, and two or three of them are of a more complex character, such as the oil of mustard-seed.

A. To the first class belong the oils of turpentine, of lemons, and of copivi balsam; these are hydrocarbons.

I. OIL OF TURPENTINE: CAMPHOGEN, OR CAMPHENE. Oil of turpentine is one of the most important of these oils, in consequence of its numerous applications in the arts, especially in the manufacture of paints and varnishes. It is obtained by distilling *turpentine* with water, with the vapour of which it readily passes over at 212°, though its boiling-point exceeds 314°. It is very sparingly soluble in alcohol. By exposure to air a part of it is converted into resinous matter, and a part into a peculiar acid matter, which, when distilled, deposits a crystallizable substance, upon exposure to cold. (*Ann. de Chim. et Phys.*, xxxi., 442,) In consequence of the great inflammability of oil of turpentine, it is highly dangerous when kept in quantities. If preserved in wooden vessels they are very apt to leak, hence the necessity of placing them in another cask, surrounded by water. In common oil of turpentine Dr. Ure found 82.35 carbon, 9.80 hydrogen, 7.85 oxygen: when purified by alcohol, the specific gravity of this oil was reduced from .888 to .878; it then appeared to be a binary compound of carbon and hydrogen, nearly resembling naphtha in composition. This suggestion, thrown out by Dr. Ure, (*Phil. Trans.*, 1822, p. 475,) has since been verified by Dumas, who deprived it of all adhering water and acid, by agitating it with quicklime, subjecting it to a careful distillation, and finally digesting it with chloride of calcium. In this state its specific gravity is .860 and its boiling-point 312°. From the density of its vapour (4.763) Dumas infers that it contains, in the 100 volumes, 500 volumes of carbon vapour (or 1000 according to the usual estimate, see p. 475) and 800 of hydrogen, and as

500	Cubic inches of	carbon vapour weigh	131.5
800	,,	hydrogen gas	17.0
100	,,	of turpentine vapour	= 148.5

These weights bear the ratio to each other of 10 equivalents of carbon to 8 of hydrogen, or

				Dumas.
Carbon	10	60	88.1	88.5
Hydrogen	8	8	11.9	11.5
Oil of turpentine	1	68	100.0	100.0

The calculated density of its vapour is 4.74; or,

5 Volumes of carbon vapour = 0.840 × 5 = 4.20
8 „ hydrogen . = 0.068 × 8 = 0.54
4.74

1. Camphor. This substance, which in many respects resembles the essential oils, being like them, volatile, inflammable, soluble in alcohol, and sparingly soluble in water, has been shown by Dumas to be an oxide of an hydrocarbon identical in composition with pure oil of turpentine, hence the term *Camphogen* or *Camphene*, applied to that oil. In its ordinary state camphor is white, semi-transparent, and concrete. Its specific gravity is .98. It fuses at about 300° in close vessels, and rises rapidly in vapour. It dissolves in the fixed and volatile oils. It is scarcely acted upon by the alkalis; some of the acids dissolve, others decompose it. (Chevreul, *Ann. de Chim.*, lxxiii.) It dissolves in sulphuric acid, forming a brown solution, from which it is at first precipitated, unaltered, by water; sulphurous acid is afterwards evolved, the solution becomes black and thick, and, after some days, affords a brown coagulum on the addition of water, and smells fragrant and peculiar. On distilling the diluted liquor, water and a yellow oil pass over, a little sulphurous acid is then disengaged, and a black matter remains in the retort, which, when digested in alcohol, affords a portion of soluble matter having some of the properties of artificial tannin. (Hatchett, *Phil. Trans.*, 1805.)

If mixed with bole or powdered clay, and repeatedly distilled, camphor is almost entirely converted into a liquid, having the characters of essential oil.

The camphor of commerce is obtained from the *Laurus camphora*, and comes chiefly from Japan. It is originally separated by distillation, and subsequently purified in Europe in a subliming-vessel somewhat of the shape of a turnip, from which the cakes of camphor derive their form. There are other trees and plants which afford it.

The specific gravity of the vapour of camphor is 5.29, which corresponds with

5 Volumes of carbon vapour . . . . = 4.20
8 „ Hydrogen gas . . . . = 0.54
$\frac{1}{2}$ „ Oxygen . . . . = 0.55
5.29

Hence, camphor appears to be the *protoxide of camphogen*, or to consist of

				Dumas.	Ure.
Carbon	10	60	79.0	79.28	78.02
Hydrogen	8	8	10.5	10.36	11.58
Oxygen	1	8	10.5	10.36	10.40
	1	76	100.0	100.00	100.00

2. Camphoric Acid. When camphor is repeatedly distilled with nitric acid, it is converted into *camphoric acid.* For this purpose, four ounces of camphor, reduced to powder by triturating it with a few drops of spirit of wine, may be introduced into a two-quart tubulated retort, placed in a sand-heat; pour upon it thirty ounces of common nitric acid, and proceed to slow distillation. When two-thirds of the acid have passed over, return it into the retort and distil as before, repeating the operation twice more; after which, as the liquor cools, a quantity of crystals of camphoric acid are deposited, which are to be washed and dried. This acid assumes the form of plumose crystals, soluble in about 100 parts of water at 60°, and in rather more than 1 part of alcohol. Its taste is acid, and somewhat acrid, and it has an aromatic odour. Exposed to heat, it sublimes unaltered. It combines with the salifiable bases, constituting a class of salts called *Camphorates.*

Camphoric acid, in its *anhydrous* state, is composed of

				Dumas.
Carbon	10	60	55.6	56.03
Hydrogen	8	8	7.4	7.32
Oxygen	5	40	37.0	36.65
	1	108	100.0	100.00

The *crystallized* acid, according to Brandes, includes 1 atom of water: it appears, therefore, that camphoric acid is $=$ (camphor $+ 4\,O$), or (camphogene $+ 5\,O$.)

Camphorates. The neutral camphorates include 6 atoms of oxygen; namely, 1 in the base, and 5 in the acid. They have a bitterish aromatic flavour, and are decomposed by the stronger acids. Subjected to destructive distillation they yield water, empyreumatic oil, and charcoal: in the air they burn with a blue or reddish flame. The camphorates of ammonia, potassa, and soda, are very soluble, deliquescent, and difficultly crystallizable: they are soluble in alcohol. The camphorates of baryta, lime, strontia, magnesia, and manganese are soluble in water. If the camphor has not been perfectly acidified the camphoric acid retains it in combination, and the salts are rendered much less soluble. The camphorate of peroxide of iron, of tin, zinc, lead, copper, uranium, protoxide of mercury and of silver, are insoluble, or nearly so.

3. Hydrate of Oil of Turpentine; Hydrate of Camphogen. Dumas has described, under this term, a crystalline compound, which is often found in mixtures of oil of turpentine and water; and, in cases where drops of water have adhered to the interior of bottles containing oil of turpentine, each drop has been found successively converted into a tuft of crystals. It is colourless, tasteless, and odourless, crystallizes in rhomboidal prisms forming stellated groups, and is heavier than water. It fuses and sublimes at temperatures of about 300° to 360°. It dissolves in 22 parts of boiling water, and crystallizes as the solution cools: alcohol and ether also dissolve it. Peligot and Dumas have observed the same compound in essential oil of cardamoms, and it is probably not an uncommon product. It consists of ($10\,car + 11\,h + 3\,O$), or of

Camphogen	1	68	71.6
Water	3	27	28.4
	1	95	100.0

4. Muriate of Camphogen; Artificial Camphor. This curious substance was discovered by Kind (*Ann. de Chim.*, li., 270); it is formed by slowly passing dry muriatic acid gas through oil of turpentine surrounded by ice, so as to keep down its temperature; the quantity of the product is very variable, but sometimes equals or exceeds that of the oil of turpentine employed, the oil absorbing a third of its weight of acid. The artificial camphor separates in the course of some hours. It is white, crystalline, of a peculiar and somewhat camphory odour, fusible below 212°, soluble in about 3 parts of pure alcohol, and deposited in crystals from a hot saturated solution. It is volatile, but not without decomposition, for when sublimed in a retort a little muriatic acid is always formed: it is decomposed by lime, and the oil evolved unaltered in its composition.

The mother-liquor, from which this muriate is deposited, is fuming, pungent, and lighter than water; when distilled, it yields a clear yellow oil, and leaves a brown residue. (Blanchet and Sell, *Jour de Phar.*, xx., 224.) Muriate of camphogen consists of $({}_{20}car + {}_{17}h + c)$, or

Camphogen	2	136	78.5
Muriatic acid	1	37	21.5
	1	173	100.0

II. Essential Oil of Lemons; Citrene. This oil is generally obtained by expression, from the exterior rind of the fruit of the lemon. (Citrus medica.) It is also obtained by distillation. In the former case the oil is extremely fragrant, but somewhat turbid, and liable to change in consequence of the presence of a little mucilage: the distilled oil is perfectly limpid and permanent.

Essence of lemons, when pure, is colourless, limpid, and very fragrant. Its specific gravity is 0.847 at 70°. It dissolves in all proportions in anhydrous alcohol, but 100 parts of alcohol, of specific gravity .837, only dissolve about 15 parts. It consists, according to the analysis of Dumas, of carbon and hydrogen in the same relative proportions as in oil of turpentine, but they are one-half less condensed, so that it may be represented by $({}_{5}car + {}_{4}h)$, or

				Dumas.
Carbon	5	30	88.1	88.5
Hydrogen	4	4	11.9	11.5
Essence of lemons	1	34	100.0	100.0

The essential oils of bergamot, and of cedrate, and probably of orange, are similarly composed.

1. Muriate of Citrene. An artificial camphor may be obtained from essence of lemons by the same process as that applicable to essence of turpentine. Blanchet and Sell (*Jour. de Phar.*) regard the essence of lemons (as also that of turpentine) as a mixture of two distinct hydrocarbons, one of which yields the crystallizable camphor, and the other the uncrystallizable fuming mother-liquor; to these they have applied the terms *citronyle* and *citryle*. According to Dumas, the crystallizable product is white, lamellar, or nacreous, fusible at 105°, and concretes into a brilliant mass on cooling. It consists of $({}_{10}car + {}_{9}h + c)$, or

Citrene	2	68	64.8
Muriatic acid	1	37	35.2
	1	105	100.0

III. Oil of Copivi. The *balsam of copivi*, which is an exudation resembling turpentine, from several species of *Copaifera*, yields, when distilled, a peculiar fragrant volatile oil, which, when deprived of water by digestion with chloride of calcium, has a specific gravity = 0.878: absolute alcohol dissolves two-fifths its weight of it, and it is soluble to any extent in ether and in sulphuret of carbon: it dissolves sulphur and phosphorus, and absorbs chlorine, which renders it viscid: when dropped upon iodine, heat and hydriodic acid are evolved. It forms, with muriatic acid, a compound analogous to artificial camphor, and also a fuming liquid. This oil, according to Blanchet, corresponds in composition and in atomic constitution with the oil of lemon.

B. The second class of essential oils, or those which are *oxides of hydrocarbon*, includes the greater number of those products: their real nature is, as yet, but imperfectly understood, but it is highly probable they are solutions of a substance analogous to camphor, in liquid hydrocarbons, and that they may, therefore, be atomically represented by $(car + h) + (car + h + o.)$ Some of these oils, when exposed to cold, yield crystalline deposits, which are modifications of camphor, or solid oxides of hydrocarbon: those from oil of peppermint and oil of aniseed have been examined by Dumas, and several others have been noticed and analyzed; the deposit from oil of roses, oil of sassafras, oil of *cinnamon* (Dumas and Peligot, *Ann. de Chim. et Phys.*, lvii., 311), and many others, which are gradually deposited, or formed by the action of air, are probably of the same nature. Such of these oils as are most dense, are, according to Dumas, most highly oxidized; some of these pass into *resins*, and others exhibit a tendency to combine with bases; this is especially the case with *oil of cloves* and *pimento*. (Bonastre, *Jour. de Phar.*, xiii.) According to Dumas, the composition of *oil of cloves* may be represented by $(20\,car + 13\,h + 5\,o)$ giving an equivalent = 173, and combining, in this proportion, with an equivalent of ammonia; so that 173 oil of cloves + 17 ammonia would form 190 of *caryophyllate of ammonia*. The crystalline deposit from oil of cloves which has been long kept, is stated by Dumas to be not only analogous to, but identical with, camphor.

§ XIV. Amygdaline. Benzule. Benzoic Acid.

Amongst the essential oils, that which is obtained by distilling the cake which remains after the fixed oil has been expressed from bitter almonds, is perhaps the most interesting. In its ordinary state, this oil is a mixture of hydrocyanic acid, and a peculiar volatile oil, neither of which pre-exist in the almond, but are produced by the action of heat and water, during the distillation, upon a peculiar principle contained in the almond, and which may be termed *amygdaline*. The essential oil may be separated from the hydrocyanic acid, by agitating it with a solution of potassa and protochloride of iron, and subjecting it to distillation, and it may then be deprived of adhering water, by redistilling it over quicklime. (Wöhler and Liebig, *Ann. de Chim. et Phys.*, li., 273.)

When thus purified, that is, deprived of hydrocyanic acid and water, the essential oil is clear and colourless, and its odour resembles that which it originally possessed: its flavour is hot and aromatic; its sp. gr. = 1.043. It is very sparingly soluble in water, but alcohol dissolves it in all proportions. It is inflammable, but it may be passed, without decomposition, through a red-hot tube. Exposed to air, or other source of oxygen, it is converted into *crystallized benzoic acid*, and this conversion is extremely rapid under the direct influence of solar light. Exposed to the joint action of air, water, and a solution of potassa, *benzoate of potassa* is formed; and if the experiment be made over mercury, the ascent of the mercury indicates the absorption of the oxygen. It is not altered by the anhydrous alkalis; but when heated with *hydrate* of potassa out of the contact of air, benzoate of potassa is formed, and hydrogen evolved.

It has been shown by Liebig and Wöhler, that the atomic constitution of this oil is such, that it may be regarded as the *hydruret* of a *base* composed of carbon, hydrogen, and oxygen, which base cannot be isolated, but may be transferred, without decomposition, from one combination to another, in the same manner as cyanogen. Combined with oxygen, this base produces *benzoic acid*, hence they have termed it *benzule.*

BENZULE is represented by $(14\,car + 5\,h + 2\,o)$: or it consists of

Carbon	14 . .	84 . .	80.00
Hydrogen	5 . .	5 . .	4.75
Oxygen	2 . .	16 . .	15.25
Benzule	1	105	100.00

HYDRURET OF BENZULE is the purified essence of bitter almonds, (deprived of hydrocyanic acid,) in which state it consists of $(\text{Ben} + h)$, or $105 + 1 = 106$: its ultimate composition being

				Dumas.
Carbon	14 . .	84 . .	79.2 . .	79.57
Hydrogen . . .	6 . .	6 . .	5.7 . .	5.56
Oxygen	2 . .	16 . .	15.1 . .	14.87
Hydruret of benzule	1	106	100.0	100.00

CHLORIDE OF BENZULE. When chlorine is passed through the above hydruret, it is absorbed, heat and muriatic acid are evolved, it becomes yellow, and when no more muriatic acid is formed, the liquid is heated; it becomes limpid and colourless, and is then pure *chloride of benzule;* its sp. gr. is 1.196: its odour is pungent and irritating, its boiling-point high, and it burns with a greenish sooty flame: when poured into water it falls to the bottom, where it remains insoluble; but by boiling, it forms crystallized benzoic acid and muriatic acid. It may be heated with baryta and lime without decomposition, but with hydrate of potassa it yields chloride of potassium, and benzoate of potassa. It dissolves phosphorus and sulphur, with the aid of heat, but deposits them in crystals as the solutions cool. With the solid chloride of phosphorus it evolves heat, produces the liquid chloride, and an oily compound of a penetrating odour. It dissolves in alcohol, and the solution soon becomes so hot as to enter into ebullition, muriatic acid is evolved, and on the addition of water benzoic ether separates.

Chloride of benzule is represented by $(\text{Ben} + c)$, or $105 + 36 = 141$ It consists, therefore, of

							Dumas.
Carbon	14	..	84	..	59.50	..	60.02
Hydrogen	5	..	5	..	3.60	..	3.51
Oxygen	2	..	16	..	11.35	..	11.55
Chlorine	1	..	36	..	25.55	..	24.92
Chloride of benzule	1		141		100.00		100.00

Iodide of Benzule is formed by distilling iodide of potassium with chloride of benzule: it passes over as a brown liquid, which concretes on cooling, and which, when freed from mixed iodine, is a white crystalline solid: it consists of (Ben $+ i$), or $105+125=230$.

Bromide of Benzule is produced by the direct action of bromine on the hydruret of benzule; it is brown, crystalline, soluble in alcohol and ether; and by continued ebullition with water is converted into benzoic and hydrobromic acids. It is represented by (Ben $+ b$), or $105 + 78 = 183$.

Sulphuret of Benzule is formed by distilling chloride of benzule with finely-powdered sulphuret of lead: it distils over in the form of an oily fluid, which concretes into a yellow crystalline mass: it smells of sulphur; water does not affect it, but when boiled with a solution of potassa, benzoate and sulphuret of potassa are formed. This compound is represented by (Ben $+ s$), or $105+16=121$.

Cyanuret of Benzule. When chloride of benzule is distilled off cyanuret of mercury a yellow oil passes over, and chloride of mercury remains in the retort. When the liquid is rectified it is colourless, but soon becomes yellow; it has a pungent irritating odour, a biting and sweetish flavour, which a little resembles that of oil of cinnamon. It is denser than water, and is converted by its action into benzoic and hydrocyanic acids: it burns with a white fuliginous flame: its symbol is (Ben $+ cy$), or $105+26=131$. The ultimate elements of this curious compound are

Carbon	16	..	96	..	73.5
Hydrogen	5	..	5	..	3.6
Oxygen	2	..	16	..	12.2
Nitrogen	1	..	14	..	10.7
Cyanuret of benzule	1		131		100.0

Benzamide. Dry ammoniacal gas is rapidly absorbed by chloride of benzule, heat is evolved, and a white crystalline solid formed, consisting of muriate of ammonia in combination with a new substance, called by Liebig and Wöhler *Benzamide*, from its analogy to oxamide. When the product is first washed in cold water, and then dissolved in boiling water, the benzamide crystallizes as the solution cools. It fuses at 240° into a limpid liquid, which concretes into a foliated mass: at a higher temperature it boils, and distils over unaltered: its vapour burns with a smoky flame. It dissolves in alcohol, and in hot ether. Triturated with caustic potassa it evolves no ammonia, but when boiled in caustic potassa, ammonia is evolved and benzoate of potassa formed. Boiled with sulphuric acid, benzoic acid sublimes and sulphate of ammonia is formed. The ultimate elements of *benzamide*, regarding it as a compound of *benzule* and *amide*, are $(14\,car + 5\,h + 2\,o) + (n + 2\,h)$, or 105 + 16 = 121, and may therefore be thus represented,

				Dumas.
Carbon . . .	14	84	69.5	69.73
Hydrogen . .	7	7	5.8	5.69
Oxygen . . .	2	16	13.2	13.05
Nitrogen . .	1	14	11.5	11.53
Benzamide . .	1	121	100.0	100.00

Hence, the action of ammonia on chloride of benzule, is such that 1 atom of the chloride, and 2 atoms of ammonia, produce 1 atom of muriate of ammonia, and 1 atom of benzamide: or,

$$\overbrace{(14\,car + 5\,h + 2\,o + c)}^{\text{1 Chloride of Benzule.}} \quad \overset{+}{+} \quad \overbrace{2\,(n + 3\,h)}^{\text{2 Ammonia.}}$$

produce

$$\overbrace{(14\,car + 7\,h + 2\,o + n)}^{\text{1 Benzamide.}} \quad \overset{+}{+} \quad \overbrace{(n + 4\,h + c)}^{\text{1 Muriate of Ammonia.}}$$

BENZINE. This substance, known under the name of *camphor* of essence of bitter almonds, is produced in the form of a crystalline deposit, when the oil is left for some weeks in contact with a strong solution of potassa; it may be purified by solution in hot alcohol and filtering through animal charcoal: as the alcoholic solution cools it forms prismatic crystals, fusible at 248°, tasteless and inodorous, and coinciding with the original oil (hydruret of benzule) in composition. (Wöhler and Liebig.)

BENZOIC ACID. $(\text{Ben} + o.)$ This acid has lately acquired much interest to the theoretical chemist, in consequence of its relation to the compound radical or base which I have just described under the name of *Benzule*, and of which it is, in fact, an oxide. Benzoic acid exists ready-formed, in benzoin or Benjamin, which is the resinoid exudation of the *styrax benzoe*, whence its name; it is found also in some of the *balsams**, and is produced by the action of heat, acids, and alkalis, on amygdaline, benzamide, and hippuric acid; lastly, it is formed by the action of oxygen on the hydruret of benzule, above described.

Benzoic acid is usually obtained by heating benzoin in a convenient vessel or apparatus, such as a crucible, with a cone of paper attached to its mouth; the acid condenses in it in fine acicular crystals, which were formerly called *flowers of benzoin.* A good process for procuring this acid is that recommended by Mr. Hatchett, which consists in digesting benzoin in sulphuric acid, when it affords, on the application of heat, a copious sublimate of pure benzoic acid. (*Additional Experiments on Tannin*, *Phil. Trans.*, 1808.) It may also be obtained by boiling a pound and a half of powdered benzoin with 4 ounces of quicklime, in 6 or 8 quarts of water. When cold, the clear liquor is decanted, and the residuum again boiled in half the former quantity of water. The liquors thus obtained are boiled down to half their bulk, filtered, and mixed with muriatic acid, as long as it occasions a precipitate, from which the liquor is poured off, and, when dry, it is put into an earthen vessel placed in a sand heat, and sublimed into paper cones.

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* Such as the balsam of tolu and of Peru.

In the tenth volume of Nicholson's *Journal*, I have detailed several experiments on benzoin, and have shown the relative quantity of acid afforded by the several processes which have been recommended for obtaining it, but different samples of benzoin afford very different relative proportions.

In making benzoic acid upon a large scale, by the process of sublimation, the better kind of benzoin is most economically employed: it may be put into an iron pot, set in brickwork over a proper fire-place; the sublimate is most conveniently received into a large wooden box lined with paper, communicating by a conical iron or tin-plate neck with the subliming pot. The first product may be sublimed a second time in the same apparatus; and, by conducting the process rather rapidly, the acid condenses in beautiful prismatic crystals, somewhat elastic. If slowly sublimed, it is more powdery. By this process of sublimation, good benzoin yields 10 to 12 *per cent.* of acid contaminated by empyreumatic oil, and which, when pressed between folds of blotting-paper, and again sublimed, is reduced to the proportion of 8 or 9 *per cent.* of the purified acid*.

Benzoic acid, when it has been thus sublimed, is in the form of soft feathery crystals, very inflammable, fusible at about 230°; it is light, of an aromatic and slightly sour taste, soluble in 25 or 30 parts of boiling water, and very sparingly soluble in cold water. It is much more soluble in alcohol; and this solution easily furnishes it pure, and in prismatic crystals. It is soluble, without immediate change, in nitric and sulphuric acids, and in many other acids by the aid of heat. The oils also dissolve it.

According to Dumas and Mitscherlich, the density of the vapour of benzoic acid is 4.27. Anhydrous benzoic acid may be represented by (Ben + *O*), that is, as an oxide of benzule; or $105 + 8 = 113$: its ultimate components therefore are

				Dumas.
Carbon	14	84	74.3	74.7
Hydrogen	5	5	4.4	4.3
Oxygen	3	24	21.3	21.0
Anhydrous benzoic acid	1	113	100.0	100.0

The *crystallized* contains 1 equivalent of water, and is represented by $(ben' + q)$, or $113 + 9 = 122$. The water cannot be expelled by heat, and is contained in most of the *benzoates*. The *benzoate of silver* is anhydrous.

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* According to Stoltze, good benzoin should yield 12 or 13 *per cent.* of pure acid by the process of sublimation; and 18 *per cent.* by the following process: dissolve 1 part of benzoin in 3 of alcohol; neutralize the solution with carbonate of soda dissolved in a mixture of 8 parts of water and 3 of alcohol: add to the mixture two parts of water and distil off the alcohol: decant the residuary liquid from the resinous deposit, and decompose it by sulphuric acid. Benzoic acid is also made by evaporating the urine of cows, horses, &c., precipitating the hippuric acid by muriatic acid, and decomposing this product by sulphuric acid: it obstinately retains an urinous odour, which may be covered by mixing it with about a twentieth part of benzoin, and subliming. In some cases, benzoic acid may be economically prepared by subjecting essence of bitter almonds to the action of the air.

BENZOATES. In the neutral anhydrous benzoates, the oxygen in the acid is to that in the base as 3 to 1: these salts are easy of decomposition, and their solutions give a precipitate of benzoic acid with the stronger acids; they give a dingy-red precipitate with the persalts of iron.

BENZOATE OF AMMONIA forms deliquescent plumose crystals, very soluble in water. Berzelius recommends this salt as a precipitant of peroxide of iron, which it throws down of an orange-red colour. Crystallized benzoate of ammonia consists, according to Thomson, of one proportional of acid, one of base, and one of water.

BENZOATE OF POTASSA is a very soluble deliquescent salt; if it be digested with benzoic acid, a *bibenzoate of potassa* results, which according to Bucholz, (*Ann. de Chim.*, lxxxiv.) forms acicular and lamellar crystals, requiring ten parts of water for their solution.

BENZOATE OF SODA forms efflorescent crystals, very soluble in water.

BENZOATE OF LIME forms acicular crystals, sparingly soluble in cold water. Vauquelin found this salt in the urine of the cow. Benzoate of ammonia forms a copious white precipitate when added to solution of chloride of calcium, which is soluble in hot water.

BENZOATE OF BARYTA is soluble and crystallizable.

BENZOATE OF STRONTIA is also a soluble salt.

BENZOATE OF MAGNESIA forms soluble plumose crystals.

BENZOATE OF MANGANESE forms beautiful prismatic crystals, which are soluble in 20 parts of cold water: and in alcohol.

BENZOATE OF IRON. Benzoate of ammonia forms an insoluble *perbenzoate* when added to solutions of peroxide of iron, of a reddish colour: in the protosalts of iron, it forms a white precipitate.

BENZOATE OF ZINC forms soluble acicular crystals when there is excess of acid: the neutral benzoate is insoluble.

BENZOATE OF TIN is insoluble, or nearly so, in water.

BENZOATE OF COPPER is a fine blue compound, difficultly soluble in water, but soluble in excess of benzoic acid, and insoluble in alcohol.

BENZOATE OF LEAD is insoluble, except there be excess of acid; it then forms nacreous crystals.

BENZOATE OF ANTIMONY has not been examined.

BENZOATE OF BISMUTH forms white acicular crystals, permanent in the air, soluble in water, and sparingly soluble in alcohol. (Trommsdorf, *Ann. de Chim.*, xi.) When benzoate of ammonia is added to acid nitrate of bismuth, it forms an insoluble white precipitate; Trommsdorf's salt therefore is probably a *bibenzoate*.

BENZOATE OF COBALT. Benzoate of ammonia forms no precipitate in solutions of cobalt.

BENZOATE OF URANIUM is a difficultly soluble straw-coloured compound, when formed by adding benzoate of ammonia to nitrate of uranium.

BENZOATE OF NICKEL. Solutions of nickel are only rendered slightly turbid by benzoate of ammonia; benzoate of nickel is probably therefore a soluble salt.

BENZOATE OF MERCURY. Benzoic acid forms white precipitates in the solutions of mercury.

Benzoate of Silver, obtained by digesting moist oxide of silver in benzoic acid, forms acicular crystals; but benzoate of ammonia produces an abundant insoluble precipitate in solution of nitrate of silver. This salt is *anhydrous*, and consists of 116 oxide of silver + 118 benzoic acid.

Benzoate of Alumina forms arborescent crystals.

§ XV. RESINS. AMBER. CAOUTCHOUC.

The Resins are solid substances which often exude spontaneously from trees and plants, or are extracted from other products by the agency chiefly of alcohol, in which they are more or less easily soluble*. They are insoluble in water; and their alcoholic solutions, when mixed with water, are rendered turbid and deposit the resin: their specific gravity varies from 0.92 to 1.20. They are brittle, and generally without much smell or taste, nonconductors of electricity, and rendered negatively electrical when rubbed. The resins fuse when heated, and are not, in their natural state, crystallizable. Some are more readily soluble in cold alcohol than others†; and some appear to include two distinct species of resin; many of them contain essential oil, which they lose by exposure to air, or which may be abstracted from them by distillation. Some of them are soluble in sulphuric acid, without decomposition‡, and are again thrown down by water. When heated, these solutions evolve sulphurous acid, and a carbonaceous deposit ensues, which contains artificial tan. They are generally decomposed by nitric acid, or considerably modified by its action. Some of them are soluble in muriatic and in acetic acids.

They combine with alkalis and salifiable bases, and form a class of compounds first studied by Hatchett, and subsequently by Unverdorben and others: in these compounds the resin performs the part of a weak acid: the resins are of great use in the arts: they constitute the basis of *varnishes**, and of many plasters and cements.

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* The resins, as they exude from trees, are often mixed with *gum*, when they form *gum-resins*, which are consequently only partially soluble in water and in alcohol; they readily dissolve in alkaline solutions when assisted by heat; and the acids act upon them nearly as upon the resins. *Ammoniacum, gamboge, assafœtida,* and *olibanum,* may be taken as examples of gum-resins.

† *Copal, mastich,* and a few other resins, are very difficultly soluble in alcohol, and contain a substance which remains in the form of a viscid matter after the resinous portion has been separated by alcohol. Copal requires peculiar management to effect its solution in alcohol. A piece suspended in the vapour of boiling alcohol is gradually softened, and, as it drops down, dissolves in the alcohol; camphor also accelerates its solution both in alcohol and in oil of turpentine. The most useful copal varnishes are those in which it is dissolved by the aid of a high temperature in linseed oil and turpentine.

Guaiacum is characterized by the singular changes of colour, which its alcoholic solution suffers when exposed to the action of nitric acid. (*Phil. Trans.* 1811.) Guaiacum is also rendered blue by the gluten of wheat, but its colour is not changed by starch; the intensity of the blue colour is said to be proportional to the quantity of gluten present in flour. (Taddei, *Giornale di Fisica*, i., 168. *Quarterly Journal*, vii., 376.) M. Pagenstecher has employed tincture of guaiacum, in conjunction with hydrocyanic acid, as a test of the presence of copper. (*Quart. Journal*, x. 182.)

‡ The properties of the resins have been ably investigated by Mr. Hatchett, the details of whose researches will be found in his communications to the Royal Society, printed in the *Philosophical Transactions* for 1804, 1805, 1806.

COLOPHONY, or common *rosin*, is the residue of the distillation of turpentine: the oil, or essence of turpentine, passes over, and the residue is a soft yellow substance which hardens by exposure to air, and is known as *white or yellow rosin:* when melted it loses water, and concretes on cooling, into *black* or common rosin. The ultimate composition of this substance may be represented by oil of turpentine + oxygen; it is a compound of

	Gay-Lussac and Thenard.
Carbon	75.944
Hydrogen	10.719
Oxygen	13.337
	100.000

PINIC ACID. According to Unverdorben (Poggen., xi., 47), when colophony is digested in cold alcohol .833 specific gravity, a portion only is dissolved; the solution thus obtained, when mixed with an alcoholic solution of acetate of copper, yields a precipitate of *pinate of copper;* this precipitate, when washed with pure alcohol and digested in a mixture of alcohol and muriatic acid, furnishes a solution from which water throws down the *pinic acid;* when washed and boiled in water, it forms on cooling a hard brittle substance, which becomes brown by fusion, passing into what Unverdorben calls *colophonic acid.* When fused with the alkaline carbonates it expels their carbonic acid; and its ethereal solution decomposes carbonate of copper with effervescence. The *pinates of ammonia, soda*, and *potassa*, are soluble in water; those of the other bases, insoluble; the pinates are mostly insoluble in alcohol, but soluble in ether.

SILVIC ACID. The resinous residue just mentioned as insoluble in cold alcohol, is soluble in boiling alcohol; and when this solution is mixed with a little sulphuric acid, it yields, on cooling, flat prismatic crystals of *silvic acid:* these two acids constitute nearly the whole of the resin, and according to Rose, (Dumas, *Ch. App. aux Arts*, v., 688,) they are *isomeric;* they both consist of

				Rose.
Carbon	40	240	79.0	79.28
Hydrogen . . .	32	32	10.5	10.36
Oxygen	4	32	10.5	10.36
	1	304	100.0	100.00

This acid is insoluble in water, fusible at about 212°, soluble in alcohol and ether, and in sulphuric acid; but when its sulphuric solution is decomposed by water, the precipitate has the properties of *pinic acid.* The *silvates* of potassa, soda, and ammonia, are soluble in water; the *silvates* of the other bases are insoluble, but they mostly dissolve in alcohol and in ether: the *silvate of magnesia*, especially, is soluble in alcohol. The alcoholic solution of silvic acid yields a precipitate in an alcoholic solution of acetate of lead: the *silvate of lead* is a white fusible powder. When alcoholic solutions of silvic acid and nitrate of silver are mixed, no precipitate falls; but on the addition of ammonia a white powder is thrown down, which is *silvate of silver*. It is soluble in alcohol and in excess of ammonia.

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* The manufacture of varnishes would be irrelevant to this work; there is an excellent article on the subject in Aikin's *Chemical Dictionary.*

Lac is a most useful substance: it has already been mentioned as a source of a dye-stuff (p. 940). It may be bleached by chlorine, and then forms excellent varnish. It is also the basis of sealing-wax. *Red-wax* is made by carefully fusing together 48 parts of shell-lac, 19 of Venice turpentine, 1 of Peru-balsam, and 32 of fine cinnabar. *Black-wax* is coloured with lamp-black: *yellow* with chromate of lead: *blue* with smalt: *green* with carbonate of copper.

Amber. This substance is commonly regarded as an antediluvian or fossil resin; it is chiefly brought from the southern coast of the Baltic, and is thrown up upon the beach between Königsberg and Memel: it also occurs in beds of brown coal, and of bituminous wood. It is transparent, or translucent, and of various shades of yellow and brown: its sp. gr. fluctuates between 1.06 and 1.07. It is considered by Berzelius as a mixture of two resins, bitumen, volatile oil, and succinic acid. When heated it fuses and burns, exhaling a peculiar and somewhat aromatic odour. It is used for various ornamental purposes; it is the basis of an excellent varnish, but it requires peculiar management to effect its solution either in oils or alcohol: *oil of amber* is used in medicine; but amber is chiefly interesting to the chemist as the source of *succinic acid*, which is exclusively obtained from it, though traces of the same acid are also found in the resins of the *coniferæ*.

Succinic Acid. The small pieces of amber which are inapplicable to ornamental purposes are used by the manufacturers of varnish, and as for this purpose the amber is heated or fused, a portion of acid and oil may be obtained from it. The common process for the preparation of succinic acid consists in subjecting amber to destructive distillation in a proper apparatus; it fuses, and then a yellowish aqueous fluid, containing acetic acid, goes over, followed by empyreumatic oil and succinic acid, part of which concretes in the receiver. When the matter in the retort suddenly subsides, the process may be stopped, for a thick dark-coloured oil would follow, which would soil the other products; and ultimately a yellow waxy matter would rise, which is yielded by most of the resins, and which has not been particularly examined. Amber is apt to be adulterated, when in small fragments, with pieces of copal, but when it is genuine, 16 ounces of it yield about half an ounce of acid, 3 ounces of oil, and 10 ounces of torrefied resin, fit for amber-varnish. When the *acid* is the only object of the operation, Julien recommends coarsely powdering the amber, and mixing with it, previous to distillation, one-twelfth part of sulphuric acid diluted with an equal weight of water; about twice as much acid, he says, will thus be obtained as when the amber is merely heated alone. (*Ann. of Phil.*, ii., 76.)

The acid as at first produced, may be purified by dissolving it in twice its weight of nitric acid, and evaporating it to dryness in a retort; a little adhering nitric acid may be washed away by ice-cold water, and pure succinic acid remains. Richter recommends, for the purification of this acid, the saturation of the sublimed product with potassa, and ebullition with powdered charcoal; the solution is then filtered, and nitrate of lead added; the resulting insoluble *succinate of lead* is decomposed by the requisite addition of dilute sulphuric acid, and the solution of succinic acid thus obtained, being carefully evaporated, affords colourless prismatic crystals of the pure acid.

When succinic acid is obtained in the form of crystals from its aqueous solutions, it is in a *hydrated* state; its specific gravity is 1.55; its taste feebly acid; it is soluble in 3 parts of boiling and about 5 of cold water: it is scarcely soluble in cold alcohol, but boiling alcohol dissolves it more freely: it is almost insoluble in oil of turpentine, by which it is distinguished from benzoic acid. It is not decomposed by chlorine, nor by nitric or sulphuric acid; it is fusible and volatile, and not decomposed by sublimation: its fusing-point is high, and when it is sublimed it loses a part, but not the whole of its water.

The substances chiefly employed for the falsification of this acid, are, according to Dumas, tartaric acid, bisulphate of potassa, and sal-ammoniac: tartaric acid is discovered by the carbonaceous residue which it leaves when heated; the sulphate, by its want of volatility; and sal-ammoniac by the odour of ammonia which it gives out when rubbed with lime.

According to Berzelius, and to F. D'Arcet, as quoted by Dumas, *anhydrous* succinic acid is composed of

				D'Arcet.	Berzelius.
Carbon	4 ..	24 ..	48 ..	48.48 ..	47.600
Hydrogen	2 ..	2 ..	4 ..	3.96 ..	4.512
Oxygen	3 ..	24 ..	48 ..	47.56 ..	47.888
Anhydrous succinic acid	1	50	100	100.00	100.000

and the *crystallized acid* includes an atom of water; so that the equivalent of the *anhydrous succinic acid* is 50, and that of the *hydrous* or *crystallized*, 59. The symbol of the former being $({}_4\,car + {}_2h + {}_3o)$ or suc'; and that of the latter $({}_4car + {}_3h + {}_4o)$ or $suc' + q$.

Succinates. In the *neutral* succinates, as in the benzoates, the oxygen in the acid is to that in the base as 3 to 1. They resemble the benzoates in appearance and in solubility, but the benzoates of lime, baryta, and mercury, are more soluble than the corresponding succinates. They are decomposed by the stronger acids, and by dry distillation; in the latter case the acid is resolved into water, an oily matter, and carburetted hydrogen and carbonic oxide.

Succinate of Ammonia forms acicular crystals, which sublime when cautiously heated. Its solution has been used as a test for iron, the peroxide of which it throws down from its neutral solutions in the form of a reddish-brown precipitate.

Succinate of Potassa is a very soluble deliquescent salt, crystallizable with difficulty in small prisms.

Succinate of Soda forms transparent four and six-sided prisms, considerably less soluble than the preceding, and permanent in the air.

Succinate of Lime forms permanent and difficultly-soluble crystals.

Succinate of Baryta is formed by adding succinate of ammonia to nitrate of baryta. A portion is thrown down in a pulverulent form, and a part, in small crystalline grains.

Succinate of Strontia may be formed as the preceding, and presents similar properties. It burns with a fine red flame.

Succinate of Magnesia is deliquescent and uncrystallizable.

Succinate of Manganese has been examined by Dr. John. (Gehlen's *Journal*, iv.) It is crystallizable, and of a slight-red tinge.

Succinate of Iron. The *protosuccinate* is crystallizable and soluble; the *persuccinate* is insoluble, and is thrown down in the form of a brownish-red flaky precipitate from solutions of the peroxide of iron. This salt has been proposed as a means of separating iron in analysis, but in the greater number of cases it is inconvenient.

Succinate of Zinc furnishes long slender crystals.

Succinate of Tin. The succinic acid dissolves protoxide of tin, and forms with it thin broad transparent crystals.

Succinate of Copper. The neutral salt is soluble, and when digested with oxide of copper yields an insoluble *subsuccinate*.

Succinate of Lead is thrown down in the form of an anhydrous powder ($\mathrm{Pl} + suc'$.) It is soluble in excess of the acid, and yields a crystallizable *bisuccinate*, and a *basic* succinate by the action of ammonia.

Succinate of Mercury is very difficultly soluble.

Succinate of Silver forms delicate lamellar crystals.

Succinone. This term has been applied to the oleaginous product of the destructive distillation of succinate of lime.

Succinamide. When ammonia acts upon dry succinic acid, heat is evolved, water is given off, and a fusible crystallizable *amide* is formed, soluble in alcohol and water. In its anhydrous state it consists, according to D'Arcet, of

			D'Arcet.
Carbon	8	48	48.93
Hydrogen	5	5	4.98
Oxygen	4	32	31.96
Nitrogen	1	14	14.13
Anhydrous succinamide	1	99	100.00

The crystallized succinamide includes 2 equivalents of water; so that the symbol of the *anhydrous* compound being ($8\,car + 5\,h + 4\,o + n$), $= 99$: that of the *hydrated* is ($8\,car + 7\,h + 6\,o + n$).

Caoutchouc. I place this curious vegetable product among the resins, though it more strictly belongs to the modifications of *hydrocarbon*, for, according to Faraday's analysis, it consists, when deprived of adhering impurities, of carbon and hydrogen only. It is obtained from the sap of several South American and Oriental plants, more especially from the *Hevæa caoutchouc*, the *Iatropha elastica*, the *Ficus Indica* and the *Artocarpus integrifolia*. It first exudes in the form of a milky juice, from which the caoutchouc gradually separates. It is insoluble in water and in alcohol, but dissolves sparingly in washed ether. Some of the liquid hydrocarbons soften and dissolve it in a very remarkable manner, and yield solutions which have been importantly applied to the manufacture of water-proof clothing. (p. 491.) It is only difficultly acted upon by acids and alkalis. It burns in the air with a bright smoky flame: when heated it fuses, and remains more or less viscid: subjected to destructive distillation, it yields a large relative proportion of a highly volatile and inflammable liquid hydrocarbon, the specific gravity of which is only 0.64. This product, which is applicable to many useful purposes in the arts, is made upon a large scale by Messrs. Enderby of London: it is a solvent of caoutchouc itself, and of other substances used as varnishes. The various applications of caoutchouc, in the manufacture of elastic articles and other useful products, are as yet probably in their infancy only: the consumption of it for water-proof and air-tight textures, is already very considerable.

§ XVI. Bitumens. Coal. Tar, &c.

Bitumens are fossil substances, bearing considerable resemblance to oily and resinous bodies, from which, and from coal, they have probably been produced by the action of subterranean fire. The chemical habitudes of several of these substances have been investigated by Mr. Hatchett. (*Phil. Trans.*, 1804.) The following are the principal varieties:

a. Naphtha has already been described as a binary compound of carbon and hydrogen. (p. 490.)

b. Petroleum has most of the properties of naphtha, but is less fluid, and darker coloured. In the countries where it abounds, it is employed for burning in lamps. By distillation, it affords a substance resembling naphtha, and mineral pitch, or asphaltum, remains in the retort.

c. Mineral-tar appears to be petroleum further inspissated. It is more viscid, and of a deeper colour.

d. Maltha, or Mineral Pitch, is a soft inflammable substance, heavier than water, and may be considered as derived from the exsiccation of mineral tar.

e. Asphaltum is found abundantly on the shores of the Dead Sea, in Albania, and in the island of Trinidad. Its colour is brown or black; it is heavier than water, and readily soluble in naphtha. Asphaltum was one of the materials used by the ancient Egyptians in embalming; hence termed *mumia mineralis*. At Babylon it was used for mortar. It dissolves in naphtha, and the solution forms a good varnish.

f. Elastic Bitumen, or Mineral Caoutchouc, is found only in the vicinity of Castleton in Derbyshire, and at Montrelais in France. It is fusible and inflammable, and when distilled *per se*, affords products corresponding to petroleum and asphaltum.

g. Mineral Adipocire, or Hatchetine, is a fatty matter found in the argillaceous iron ore of Merthyr: it is fusible at about 160°, and inodorous when cold, but of a slightly bituminous odour when heated, or after fusion.

The above substances are insoluble in water, and difficultly soluble in alcohol, with the exception of naphtha and petroleum, which are soluble in highly-rectified alcohol. Some of them are hydrocarbons, and some contain small relative proportions of oxygen.

h. Retinasphaltum is a substance which accompanies the Bovey-coal of Devonshire. I have also found it in some of the Staffordshire-coal. It was first analyzed by Mr. Hatchett, who found it to consist of 55 resin, 41 asphaltum, 4 earthy matter and loss.

i. Pit-coal. There are three chemical varieties of this important substance. 1. The first, or *brown-coal*, retains some remains of the vegetables from which it has originated. When heated, it exhales a bituminous odour, and burns with a clear flame. It is generally of a tough consistency, and yields, according to Mr. Hatchett, a portion of unaltered vegetable extract, and resin. 2. The second variety, or *black-coal*, is the ordinary fuel of this country. It exhibits few or no traces of vegetable origin, and consists principally of bitumen and charcoal, in variable proportions. When exposed to heat, it swells, softens, and burns with a bright flame, leaving a small quantity of ashes. Many varieties, however, abound in earthy matter, and these produce copious cinders, and burn with a less intense heat. The products of the destructive distillation of this kind of coal have been already described. (p. 495.) The residue is a hard, sonorous charcoal, termed *coke*, and containing the earthy ingredients of the coal. 3. The third variety, or *glance-coal*, consists almost entirely of charcoal and earthy matter. It burns without flame, and, when distilled, yields scarcely any gaseous products. All the varieties of common coal contain nitrogen, and afford ammonia when subjected to destructive distillation. In consequence of the enormous quantities of pit-coal distilled for the production of illuminating-gas, a part of the commercial demand for ammoniacal salts is now supplied from that source. Dr. Thomson arranges the different kinds of British coal under the following divisions. (*Ann. of Phil.*, xiv.) 1. *Caking-coal;* 2. *Splintery-coal;* 3. *Cherry-coal*, which is less hard and more slaty in fracture; 4. *Cannel-coal:* such as that from Wigan in Lancashire. These varieties he states to be composed as follows:

	Caking-coal.	*Splint-coal.*	*Cherry-coal.*	*Cannel-coal.*
Carbon	75.28	75.00	74.45	64.72
Hydrogen	4.18	6.25	12.40	21.56
Nitrogen	15.96	6.25	10.22	13.72
Oxygen	4.58	12.50	2.93	0.00
	100.00	100.00	100.00	100.00

The proportion of nitrogen here given appears enormous. Dr. Ure (*Phil. Trans.* 1822, p. 467) obtained the following results:

	Cannel-coal.	*Splint-coal.*
Carbon	72.22	70.90
Hydrogen	3.93	4.30
Nitrogen	2.80	0.00
Oxygen	21.05	24.80
	100.00	100.00

Dr. Henry regards Dr. Ure's results, as far as concerns the oxygen, to be the most correct, but he always obtained *ammonia* from both the above varieties of coal, and therefore infers the existence of nitrogen, though scarcely to the extent given by Dr. Thomson. The following are Dr. Thomson's results, as to the volatile products, coke and ash, in

	Volatile products.	*Weight of Coke.*	*Incombustible Ash.*
1000 parts of caking-coal	226	774	15
———— splint-coal	352	647	95
———— cherry-coal	477	522	100
———— cannel-coal	600	400	110

k. Peat and Turf consist principally of the remains of vegetables, having undergone comparatively little change. They often contain bituminous wood, branches and trunks of trees, and vegetable extract.

l. Mellilite, or Honeystone, is a rare substance, found in the brown-coal of Thuringia, and in Switzerland. It is of a honey-yellow colour, crystallized in octoëdra, and, when analyzed by Klaproth, was found to consist of alumina combined with a peculiar acid, which has been termed *Mellitic acid.*

Mellitic Acid is obtained by digesting the native *mellitate of alumina* in carbonate of ammonia or potassa, decomposing the resulting alkaline salt by acetate of lead, which produces an insoluble *mellitate of lead*, and which, diffused through water, and exposed to a current of sulphuretted hydrogen, yields sulphuret of lead, and the *mellitic acid* is set free. It has a peculiar sour, bitter, and sweet taste, is very soluble in water and alcohol, and crystallizes in white needles: it is not altered by nitric or muriatic acid, but is modified when boiled with anhydrous alcohol: it has been analyzed by Liebig and Wöhler (*Ann. de Chim. et Phys.*, xliii., 200), who consider it, in its *anhydrous* state, as an acid of carbon, composed of 4 atoms of carbon + 3 of oxygen, and containing, in its *hydrated* state, 1 atom of water. So that, in the latter state, it may be represented by $({}_{4}car + {}_{4}o + h)$, or $({}_{4}car + {}_{3}o + q)$. Its analogy to oxalic acid is obvious: its salts are less soluble than the oxalates.

Tar. This term is applied to one of the products of the destructive distillation of organic substances, and is designated, according to its source, *vegetable-tar*, *coal-tar*, and *animal-tar.* It is brown or black, of a thick consistency, and a strong and peculiar odour, varying with its source. It has been frequently subject of experiment, but has lately acquired peculiar interest from the researches of Reichenbach, who has obtained from it several definite compounds, of which the most remarkable are the following:

1. Paraffine. When beech-tar is distilled, three liquids pass into the recipient; 1. a light oil; 2. an aqueous acid; 3. a heavy oil. The *heavy oil* is subjected to several redistillations, and then sulphuric acid is gradually added to it, till the mixture becomes a black and thin liquid: and if it does not spontaneously rise in temperature to 212°, it is to be heated up to that point: the mixture is then kept for twelve hours, or more, at a temperature of about 122°, when a colourless oil will be found floating upon its surface, which is to be carefully poured off, and, on cooling, the *paraffine* concretes upon its surface: it is to be removed, washed, and pressed in folds of bibulous paper, and finally purified by solution in hot anhydrous alcohol, from which it separates, on cooling, in a solid form; it is somewhat flexible, and not greasy; crystalline, tasteless, and odourless: at 112° it fuses into a transparent oily liquid, and at a higher temperature boils and distils without change: its vapour burns with a white sootless flame. Its specific gravity is 0.870. Its name is derived from its inertness as a chemical agent, or its want of affinity. (*parum affinis.*) It resists the action of acids, alkalis, chlorine, and potassium, and cannot be united by fusion with camphor, naphthaline, benzoin, or pitch; but it unites with stearine, cetine, bees'-wax, colophony, and readily dissolves in oil of turpentine and in naphtha. 100 parts of ether dissolve

140 of paraffine at the temperature of 75°; at a lower temperature the solution concretes into a white crystalline mass. It separates from its hot alcoholic solution in crystalline laminæ, when not too concentrated. According to J. Gay Lussac (*Ann. de Chim. et Phys.*, L. 78,) it is a binary compound of carbon and hydrogen, and its elements are in the same ratio as those of olefiant gas, &c., but as the density of its vapour has not been determined, its atomic constitution, and its equivalent, remain unascertained. Paraffine appears to exist in the fossil wax of Moldavia (Magnus, *Ann. de Chim. et Phys.*, lv. 217,) and in the product of the distillation of bituminous schist. (Laurent *ibid.* liv., 392.)

Eupion. This liquid was also discovered by Reichenbach. (*Ann de Chim. et Phys.*, L. 69.) It is associated with paraffine; but it is most abundant in *animal tar*, especially that obtained from horn or bones. This tar is distilled, so as to obtain about five-eighths of product, and this is again distilled, so as to yield about three-eighths: this last product is mixed with an eighth of sulphuric acid, and the lighter yellow liquid which then separates is poured off, mixed with its weight of sulphuric acid, and distilled; a colourless liquid passes over, which is to be mixed with a solution of potassa; after some time, it separates upon the surface of the mixture, when it is to be poured off, mixed with a fourth its weight of sulphuric acid, and again distilled, washed with hot solution of potassa, decanted off as before, and slowly distilled with water till three-fourths have passed over: this ultimate product is placed in vacuo for 24 hours, then heated to its boiling-point with a few grains of potassium, and when it no longer is at all acted on by that metal, it is allowed to cool and poured from the deposits: it is then *eupion*. If it contain paraffine, the two may be separated by distillation with water, and the first portions which pass over are then entirely free from it.

Eupion is tasteless, colourless, inodorous, very limpid, specific gravity 0.74; it remains liquid at −4°, and boils at about 340°, distilling over without change. It is a non-conductor of electricity. Its vapour burns with a pure white flame. It is insoluble in water. 100 parts of alcohol at 66°, dissolve 33 parts, but at a lower temperature the greater part of the eupion separates. Acetic ether dissolves about a third of eupion; sulphuret of carbon, oil of turpentine, naphtha, and almond and olive oil readily mix with it: it dissolves chlorine and bromine, and again evolves them when heated: with iodine it forms a blue solution: aided by heat it dissolves phosphorus, sulphur, and selenium, but deposits the greater portion on cooling. It dissolves naphthalin, camphor, stearin, cetine, cholesterine, and paraffine, at common temperatures, and more abundantly when heated. Caoutchouc swells in it, and dissolves when heated, but the solution remains glutinous when spread upon a surface, except it be dried by heat. The acids and alkalis are without action on eupion, and it is not altered by exposure to air. It has not been analysed. Its name is derived from ευ, *well*, and πιων, *greasy*, for it has the greasiness of a fixed oil.

Kreosote, or Creosote (from κρεας, *flesh* and σωζω, *I save.*) This interesting product was discovered also by Reichenbach, (*Ann. de Chim., et Phys.*, liii. 325.) It is obtained from *wood-tar*, which is subjected to distillation till the residue has the consistency of pitch; but the process should not be urged too far. *Oil*, and acid water pass over; the former is separated, and distilled in a glass retort (not to dryness), when two products are again obtained, of which the acid water is rejected as before, and the oil preserved. In these distillations, the oil which first passes over is lighter than that which succeeds, its density augmenting with the heat: the lighter oil contains but little kreosote, and consists chiefly of eupion and lighter products: the *heavy* portion is pale-yellow, but becomes brown by exposure to air; it has a disagreeable odour, and tastes caustic, sour, sweet, and bitter. To this heavy oil, carbonate of potassa is added as long as it effervesces; it is then poured off from the produced acetate of potassa, and redistilled (not to dryness): the lighter part is again rejected, and the heavy oil is now dissolved in a solution of caustic potassa of the specific gravity; 1.12: heat is evolved, and an insoluble compound of eupion, and other oils, floats upon the surface and is removed. The alkaline solution is then gradually heated in an open capsule to its boiling-point; it rapidly absorbs oxygen, and becomes brown; it is suffered to cool in the air, and then dilute sulphuric acid is added, which causes the oil to separate. This oil is now mixed with water and a little caustic potassa, in a retort, and the mixture subjected to rapid ebullition; but in consequence of the feeble tension of kreosote vapour at 212°, it passes slowly over; at length a period arrives when, although much oil remains in the retort, but little passes over, notwithstanding the heat is raised: it is then time to stop the process; the residue contains *picamar*, sulphate and acetate of potassa, and a brown substance.

The oil in the receiver is now separated from the water, and again dissolved in a similar solution of potassa: a portion of light insoluble oil separates as before, which, being removed, the mixture is heated in an open vessel as before, and as it slowly cools, it again becomes brown, but less so than formerly; sulphuric acid is then added in slight excess, and the evolved oil is washed, as long as it is acid, with cold water. The distillation of this oil with water is again repeated, but, instead of adding potassa, a little phosphoric acid is employed to abstract a portion of ammonia which the oil still retains. The distilled oil is now, for the third time, dissolved in the caustic potassa, and if the precautions above described have been attended to, they combine without the separation of any oily matter, and the mixture, exposed to air, only acquires a slight red tinge. When the kreosote is now ultimately separated from its combination with the potassa, it is sufficiently pure for medical use: to obtain it absolutely pure, it must be distilled with water, and this hydrated product again rectified: water first goes over, and afterwards, at a high temperature (203° Cent.), the kreosote: to deprive it absolutely of water, its vapour must be passed over chloride of calcium.

I have copied the above details from Dumas: the process, though not difficult, is, as he observes, very troublesome, but methods of improving and facilitating it will doubtless be discovered.

Kreosote, when pure, is a colourless transparent liquid, of great refractive power, a penetrating and strong odour resembling that of smoked meat: it has a burning caustic taste: its specific gravity is 1.037 at 65°; it boils at 397° (203° Cent.); and retains its fluidity at $-17°$. It is a non-conductor of electricity, and it burns with a very sooty flame.

When mixed with water, two solutions result; the one consisting of 1.25 kreosote + 100 water; the other, of 100 kreosote + 10 water. The aqueous solution is neither acid nor alkaline.

Pure kreosote dissolves oxide of copper, forming a brown solution: when boiled with peroxide of mercury, it is reduced, and the kreosote converted into a resin. It produces effervescence and red fumes with nitric acid: it absorbs chlorine and is gradually changed by it into a resin. It is coloured by bromine, iodine, sulphur and phosphorus. With potassium it evolves gas, and potassa is formed, which combines with the kreosote. It is thickened and blackened by concentrated sulphuric acid. Acetic acid is its most perfect solvent. It forms two compounds with potassa; the one anhydrous, liquid, and of an oily consistence; the other hydrated, and crystallizable in nacreous plates. All the acids decompose these compounds, and separate unaltered kreosote. With soda it produces similar combinations. It also combines with ammonia, lime, and baryta. It dissolves many salts. Alcohol, ether, sulphuret of carbon, eupion, naphtha, and acetic ether, dissolve it in all proportions. It does not combine with pure paraffine. It dissolves the resins, and all colouring-matters, including those of cochineal, saunders-wood, dragons'-blood, madder, saffron, and with the aid of heat, indigo. Its action upon Caoutchouc, unlike that of eupion, is very feeble.

Kreosote immediately coagulates egg-albumen, although much diluted; it also coagulates serum. Meat and fish are preserved after having been brushed over with kreosote and dried in the sun; and it appears to be the principle to which the antiseptic powers of wood-smoke, and pyroligneous acid, are due. Its action upon the animal system is energetic; it is painful upon the tongue, destroys the epidermis, and kills fishes and insects: it also destroys vegetation. It is medicinally employed in tooth-ach, cancer, ulcers, and cutaneous diseases, externally; and to check hæmorrhage; and internally as a stimulant, and for the prevention of nausea and vomiting. Three or four drops, added to a pint of ink, effectually prevents its mouldiness. According to Ettling, (*Ann de Chim. et Phys.*, liii. 333,) it consists of 77.42 carbon, 8.12 hydrogen, 14.46 oxygen; but, as it probably retains a variable portion of water, its atomic constitution cannot be accurately inferred.

Picamar. This is the *bitter principle* of tar; whence it derives its name (*Picis amarum.*) It is contained in the *heavy oil of wood-tar;* that portion, the sp. gr. of which exceeds 1.095, is mixed with 8 parts of a solution of potassa, sp. gr. 1.15, and left to itself: a layer of impure eupion and paraffine separates upon the surface, after which the liquor clears, and in 24 hours deposits brilliant acicular or lamellar crystals; these are dried between folds of blotting-paper, and repeatedly dissolved in boiling solution of potassa, till the mother-liquors are colourless, and the crystals buff-coloured: they are then decomposed by dilute phosphoric acid, which combines with the potassa, and separates a brownish limpid oil, which, after having been two or three times redistilled with water acidulated by phosphoric acid, is ultimately carefully rectified without addition. The product thus obtained is *picamar.* It is almost colourless and transparent; its consistency is that of oil, and it is greasy. It is insupportably bitter, with an aroma like peppermint; its sp. gr. is

1.10 at 65°. It boils at 545°, being less volatile than kreosote. Nitric and hot sulphuric acid decompose it: it dissolves in acetic acid, and is the source of the bitter flavour of crude pyroligneous acid. It is soluble in all proportions in alcohol, and in sulphuric and acetic ether, and in kreosote. It neither dissolves paraffine, asphaltum, nor amber: it takes up caoutchouc when hot, but deposits it again on cooling. It forms crystallizable compounds with potassa, which are almost insoluble in pure alcohol: weak alcohol dissolves the crystals when hot, but deposits them again as it cools. When impure, these crystals gradually become brown or blue. It also combines with ammonia, soda, lime, and baryta, but the bases are not neutralized in any of these compounds. Picamar reduces red oxide of mercury to the metallic state, and minium to the state of protoxide.

Pittacal. When a few drops of baryta-water are added to an alcoholic solution of impure picamar, or even of oil of tar, deprived of its acid, the liquor immediately assumes a bright-blue tint, which in a few minutes passes into an indigo colour. Dumas considers this substance identical with a blue product obtained, in 1827, from coal-tar, by MM. Barthe and Laurent. Reichenbach gave it the above name, from πιττα, *pitch*, and καλλος, *ornament*.

The mode of separating pittacal has not been clearly described: Dumas states, that when precipitated in a flocculent state from its solutions, or obtained by evaporation, it closely resembles indigo, and, like it, acquires a coppery hue when rubbed: it is inodorous, tasteless, and not volatile: at a high temperature it becomes charred without evolving ammonia. It is decomposed by nitric acid; muriatic and dilute sulphuric acid dissolve it; and it is abundantly soluble in acetic acid, forming a red liquid, which, when saturated by an alkali, becomes of a bright blue. Reichenbach represents it as a more delicate test of acids and alkalis than litmus. It is insoluble in alcohol, in ether, and in eupion. With acetate of lead, protochloride of tin, ammonio-sulphate of copper, and acetate of alumina, it yields a fine blue colour with a tint of violet: these combinations may probably be useful as dye-stuffs, for they are not affected by air or light. It is said, like indigo, to contain nitrogen, but its ultimate composition has not been accurately determined.

Capnomor, (καπνος, *smoke*, and μοιρα, *part*, because it forms part of wood-smoke.) This is a colourless transparent liquid of a pungent and rather agreeable odour, which occurs with the above products in the heavy oil of tar. When that oil is digested with solution of potassa, the kreosote, picamar, and pittacal are taken up, and *capnomor*, with a little eupion floats upon the surface: this is separated and mixed with sulphuric acid, which dissolves the capnomor and leaves eupion; carbonate of potassa separates the capnomor from its acid combination, and it is purified by distillation. Its specific gravity is 0.975: it boils at 365°. It is insoluble in water and the alkalis, but soluble in alcohol, in ether, and in eupion. Its composition has not been determined.

The above is an outline of the history of the extraordinary products contained in tar: when considered in reference to the various hydrocarbons already noticed, as producible from coal-tar, and by the destructive distillation of resins and oils, the whole subject acquires a considerable degree of interest, and leaves little doubt that the apparent complexity and incongruity which hangs over the inquiries as they now stand, will be done away by the further examination of their mutual relations, and by the attainment of more exact views of their ultimate and atomic constitution.

§ XVII. VEGETABLE ACIDS.

This Section will be devoted to the *tartaric*, *oxalic*, *citric*, and *malic acids*, which are the principal of those found ready-formed in our common fruits, and are of important application in the arts and domestic economy, and to a few other acids of more rare occurrence, or which, by analogy, may be ranked with the above.

1. Tartaric Acid. Scheele first obtained crystallized tartaric acid in the year 1770. It exists *free* in the pulp of tamarinds, in grapes, and in the pepper-plant: as *tartar*, in tamarinds, grapes, mulberries, and samphire; in the root of wheat (*Triticum repens*), and of dandelion (*Leontodon taraxacum*), in the berries of sumach (*Rhus coriaria*), and in the rhubarb-plant, the potato, madder, and Iceland-moss: as *tartrate of lime* in squills, madder-root, quassia-wood, the fruit of *Rhus typhinûm*, and the tubercles of the *Helianthus tuberosus*. (Gmelin.)

Tartaric acid is generally obtained from the *bitartrate of potassa*. Mix 100 parts of this salt in fine powder with 30 of powdered chalk, and gradually throw the mixture into 10 times its weight of boiling water: when the liquor has cooled, pour the whole upon a linen strainer, and wash the white powder which remains with cold water: this is a *tartrate of lime;* diffuse it through a sufficient quantity of water, add sulphuric acid equal in weight to the chalk employed, and occasionally stir the mixture during 24 hours; then filter, and carefully evaporate the liquor to about one-fourth its original bulk; filter again, and evaporate with much care nearly to dryness; redissolve the dry mass in about six times its weight of water, render it clear by filtration, evaporate slowly to the consistency of syrup, and set aside in a warm place to crystallize. By two or three successive solutions and crystallizations, tartaric acid will be obtained in nearly colourless crystals; they may be perfectly whitened by the aid of a little animal charcoal. Tartaric acid may also be obtained by neutralizing 1 part of tartar by carbonate of potassa, and digesting the solution for an hour with 8 parts of quicklime, decanting the liquor (which contains caustic potassa) washing the residue with dilute acetic or muriatic acid to free it from excess of lime, and then decomposing it by dilute sulphuric, as above. (*Osann.*) Dr. Henry states, that in this process the free potassa prevents the precipitation of the tartrate of lime. Fabbroni obtained tartaric acid by adding excess of powdered tartar to a boiling mixture of 1 part of sulphuric acid and 3 of water; the solution, on cooling, deposits some tartar and sulphate of lime, from which it is poured off and evaporated to a small bulk; alcohol is then added, which dissolves out the tartaric acid, and leaves bisulphate of potassa. (*Ann. de Chim. et Phys.*, xxv., 9.) Tartaric acid may also be obtained by decomposing *tartrate of lead*, diffused through water, by sulphuretted hydrogen.

Crystallized tartaric acid is intensely sour: its specific gravity is 1.6: it is generally semitransparent, and of complicated forms: these appear to be modifications of a rhombic prism. (Brooke, *Ann. of Phil.*, 2nd series, vi., 118. Peclet, *Ann. de Chim. et Phys.*, xxxi., 78.) It is not altered in a dry atmosphere, but in humid air it tends to deliquescence. At a little above 212° it melts into a transparent liquid, boils at 250°, and, on cooling, concretes into a granular mass, which is more deliquescent than the original acid. If the heat be continued, it becomes yellow, exhales a peculiar odour, and begins to be decomposed. Water dissolves 1.5 its weight of tartaric acid at 60°, and twice its weight at 212°. The concentrated solution has the consistence of syrup. The solubility of this acid is, however, variously stated, and it is not easy, under common circumstances, to dissolve more than 1 part of the crystals in 4 or 5 water, but when a boiling solution is cooled to 60°, it retains much more. It is also soluble in alcohol. The aqueous solution of tartaric acid soon becomes mouldy, and suffers decomposition. Boiled in nitric acid, tartaric acid is partly converted into oxalic acid; and sulphuric acid converts it into acetic. It becomes converted into oxalic acid by fusion with potassa.

When tartaric acid is submitted to destructive distillation, it affords a brown acid liquor, containing an oily matter, acetic acid, pyroacetic spirit, and pyrotartaric acid. If this liquor, after having been passed through a wet filter to separate the oil, be saturated with carbonate of potassa, and evaporated to dryness, a saline mass is obtained, which, after having been twice or thrice redissolved and crystallized, is rendered free from foreign matter. If this salt be distilled with sulphuric acid, diluted with its weight of water, an acid liquor passes over, succeeded by a white sublimate of pure *pyrotartaric acid.* Rose, who has examined the properties and combinations of this body, considers it as a distinct acid; the *pyrotartrates of ammonia*, *potassa*, *soda*, *baryta*, *strontia*, and *lime*, are very soluble. The pyrotartaric acid occasions precipitates in acetate of lead, and in nitrate of mercury, and is thus, according to Rose, distinguished from tartaric acid, which only throws down the former;—but this is not a correct distinction.

Tartaric acid is distinguished by the white granular precipitate which it produces when added in excess to solutions containing potassa. It produces a white precipitate, soluble in excess of acid, in lime, baryta, and strontia-water, and in acetate of lead. It is used in calico-printing, and is much employed as a cheap substitute for citric acid in lemonade and effervescent solutions: in the laboratory it is used as a test of the salts of potassa, and to prevent the precipitation of certain oxides, as that of antimony, and the titanic acid.

Tartaric acid, as it exists in *anhydrous* combination with bases, may be represented by the equivalent 66, (66 Thomson, 66 Gmelin, 66.48 Turner,) and its hypothetical composition in reference to this atomic weight will be $({}_{4}car + {}_{2}h + {}_{5}o)$, or

				Berzelius.
Carbon	4	24	36.36	35.980
Hydrogen	2	2	3.03	3.807
Oxygen	5	40	60.61	60.213
	1	66	100.00	100.000

The *crystallized* acid is constituted of

				Berzelius.
Anhydrous tartaric acid	1	66	88	88.06
Water	1	9	12	11.94
	1	75	100	100.00

Tartrate of Ammonia ($tar'+\text{A}$) forms very soluble prismatic crystals, of a cooling taste. The addition of tartaric acid to its aqueous solution, produces a precipitate of a difficultly-soluble *bitartrate* of ammonia. When a saturated solution of tartaric acid is added to strong liquid ammonia in such proportions as to form the bitartrate, the liquids solidify with great rise of temperature.

Tartrate of Potassa ($tar'+\text{P}$) is formed by saturating the excess of acid in *tartar*, by potassa. The resulting salt is soluble in less than twice its weight of water, (hence, in opposition to the bitartrate, termed *soluble tartar.*) It crystallizes in four and six-sided prisms with diëdral summits, but its primitive form is a right rhomboidal prism. (Brooke, *Ann. Phil., N.S.*, vii., 161.) Its taste is saline and bitter, and it is used in medicine, (formerly under the name of *Tartarus tartarisatus,*) as an aperient. It is slightly deliquescent, and almost insoluble in absolute alcohol. Most acids occasion a precipitate of bitartrate of potassa when added to the aqueous solution of this salt. Tartrate of potassa is anhydrous, and consists of

				Thomson.	Berzelius.
Potassa	1	48	42.1	42	41.31
Tartaric acid	1	66	57.9	58	58.69
	1	114	100.0	100	100.00

Bitartrate of Potassa; Supertartrate of Potassa; Tartar. ($2\,tar'+\text{P}$.) This substance exists in considerable abundance in the juice of the grape, and is deposited in wine casks in the form of a crystallized incrustation, called *argol,* or *crude tartar.* It is purified by solution and crystallization, which renders it perfecty white: when in fine powder, it is termed *cream of tartar.* The purification of *tartar* at Montpellier is performed as follows:—It is first dissolved in boiling water, and crystallized; these crystals are then boiled with one-twentieth their weight of pipe-clay, (and the same quantity of animal charcoal?) which absorbs the colouring-matter, and falls as an insoluble sediment, the crystals of pure tartar separating afterwards upon the surface of the liquor, and upon the sides and bottom of the boiler; the term *cream of tartar* was originally applied to the imperfectly-crystallized superficial crust. The details of this process are described by M. Fizes, (*Mémoires de l'Académie*, 1725,) and it is still carried on upon the same plan. The Venetian process for the purification of tartar consists in the separation of the grosser impurities by one or two preliminary solutions and crystallizations, after which, white of egg and wood-ash are added to the boiling solution of the crystals, and the impurities skimmed off during the effervescence which ensues. (Desmaret, *Journ. de Phys.*, i., 67.)

Bitartrate of potassa may be formed artificially by adding excess of tartaric acid to a solution of potassa. The mixture presently deposits crystalline grains, and furnishes a striking example of the diminution of solubility by increase of acid in the salt. Upon this circumstance, the use of tartaric acid as a *test* for potassa depends, for soda forms an easily-soluble supertartrate, and consequently affords no precipitate.

Its crystals, which are irregular six-sided prisms, terminated by hexaëdral summits, or triangular prisms with diëdral summits, have been described by Dr. Wollaston, (Thomson's *Annals*, x., 37,) and by Mr. Brooke, (*Ann. of Phil., N. S.,* vii., 161.) They include one proportional of water, which is not separable at a heat much below that at which the acid of the salt begins to be decomposed. They are hard, and taste gritty and subacid.

The specific gravity of this salt is 1.95. It requires 95 parts of water at 60°, and 15 parts at 212° for its solution. It is rendered much more soluble by the addition of boracic acid or of borax, as was first observed by Le Fevre. (*Mém. Paris*, 1732.) Two parts of borax, and five of crystals of tartar in powder, are soluble in about six times their weight of boiling water; on evaporating the solution to the consistency of honey, the residue concretes into *Le Fevre's soluble cream of tartar*, or *sal-gummosum.* It is the *tartarus boraxatus* of some old writers. When exposed to heat, tartar fuses, blackens, and is decomposed, and carbonate of potassa is the remaining result. Provided the tartar be free from lime, which however is seldom the case, this furnishes a good process for obtaining pure *carbonate* of potassa. By destructive distillation, Fourcroy and Vauquelin obtained the following residuary substances from 1000 grains of crystals of tartar. (*Ann. de Chim.*, lxiv., 43.)

Carbonate of potassa	350	Alumina	0.25
Carbonate of lime	6	Iron and manganese	0.75
Silica	1.2		

The aqueous solution of tartar becomes mouldy when exposed to air, and the tartaric acid being entirely decomposed leaves a weak solution of carbonate of potassa. Tartar sometimes acts as a simple acid, and dissolves oxides insoluble in most other acids; hence Gay Lussac has suggested its use in certain analyses. (*Ann. de Chim. et Phys.*, iii., 281.) By the action of excess of caustic potassa, at high temperatures, tartar is converted into oxalate of potassa. The component parts of tartar render it an excellent flux in the reduction of metallic ores upon a small scale, its alkali promoting their fusion, and the carbonaceous matter tending to reduce the oxides. Tartar is sometimes adulterated by the addition of pounded quartz, and by calcareous spar; the former may be detected as an insoluble residue by boiling the powdered tartar with half its weight of carbonate of potassa or of borax in 8 parts of water; the latter produces effervescence with dilute muriatic acid. A small portion of tartrate of lime is almost always present in the purified tartar; it separates in tufts of acicular crystals from the hot solution of the tartar.

TARTRATE OF POTASSA AND AMMONIA is formed by saturating the excess of acid in tartar with ammonia. It forms transparent four and six-sided prisms, very soluble in water, and which effloresce and lose ammonia by exposure to air.

TARTRATE OF SODA ($tar' + \mathrm{S}$) forms acicular crystals, soluble in about their own weight of water, and insoluble in absolute alcohol. They contain, according to Bucholz, 16 *per cent.* (2 equivalents) of water. When their aqueous solution is mixed with half their weight of tartaric acid, it yields small prismatic crystals of *bitartrate of soda*, of an acid taste, soluble in 8 parts of cold and 1.8 of boiling water, and containing about 15 *per cent.* (3 equivalents,) of water of crystallization. (Gehlen's *Journ.*, v., 520.) Tartrate of soda is often formed extemporaneously by dissolving equal parts of powdered tartaric acid and of bicarbonate of soda, in separate portions of water, and then mixing the solutions; if taken during the effervescence, it forms a refreshing saline and slightly aperient draught.

Tartrate of Potassa and Soda ($2\,tar' + P + S$) is prepared by saturating the excess of acid in tartar, with carbonate of soda; it is the *soda tartarizata* of the *Pharmacopœia;* it forms prismatic crystals, the forms of which have been described by Mr. Brooke. (*Ann of Phil. N. S.*, v., 451.) It has long been used in pharmacy under the name of *Rochelle Salt* and *Sel de Seignette.* The crystals are soluble in about 5 parts of cold water, and consist of

				Schulze.		Vauquelin.
Potassa	1	48	15.9	14.3	Tartrate of Potassa	54
Soda	1	32	10.6	13.3		
Tartaric acid	2	132	43.7	41.3	Tartrate of Soda	46
Water	10	90	29.8	31.1		
	1	302	100.0	100.0		100

Tartrate of Lithia is easily soluble; when its solution is evaporated it affords a white uncrystallized mass, opaque and not deliquescent. Excess of tartaric acid does not give a crystallizable bitartrate. *Tartrate of Potassa and Lithia*, formed by saturating tartar with carbonate of lithia, affords quadrangular prismatic crystals, easily soluble, and very slightly efflorescent. *Tartrate of Soda and Lithia* forms rectangular four-sided prisms, easily soluble, slightly efflorescent, and of a pure saline flavour. (C. Gmelin.)

Tartrate of Lime is nearly insoluble in cold water, but soluble in 600 parts of boiling water; it is produced by adding chalk to tartar, as in the process for obtaining tartaric acid, where it is decomposed by sulphuric acid. It dissolves sparingly in excess of tartaric acid, and may be obtained from such solution in small silky crystals. It is often contained in rough and purified tartar, and forms tufts of acicular crystals when tartar is saturated by bases. Dilute muriatic acid dissolves and decomposes it: if this solution is saturated by ammonia, the tartrate of lime is reproduced, and crystallizes after some hours in acute octoëdra. Solution of potassa dissolves tartrate of lime, and when concentrated by evaporation becomes gelatinous, but liquefies on cooling. (Dumas.) Tartrate of lime, after desiccation at 212° consists of

				Berzelius.	Gay Lussac and Thenard.
Lime	1	28	21.45	21.64	22.423
Tartaric acid	1	66	50.85	50.55	77.577
Water	4	36	27.70	27.81	
	1	130	100.00	100.00	100.000

Tartrate of Potassa and Lime may be formed by adding lime-water to solution of supertartrate of potassa, till it begins to become turbid: in a few days acicular crystals of the triple salt are deposited, which effloresce when exposed to air?

Tartrate of Baryta ($tar'+\text{B}$) is a difficultly-soluble salt. When carefully dried it is anhydrous: it is distinguished from sulphate of baryta by its solubility in muriatic, nitric, and acetic acids, and by its destructibility by heat.

Bitartrate of Baryta forms transparent crystals, consisting of two proportionals of tartaric acid $(66\times 2)=132$, one of baryta $=77$, and two of water $(9\times 2)=18$. (Thomson.)

Tartrate of Strontia is thrown down, after some hours, on mixing the solutions of tartrate of potassa and nitrate of strontia. It dissolves in rather more than 300 parts of boiling water, and forms small rhomboidal crystals as the solution cools. (Vauquelin.) It consists of 1 atom of tartaric acid, 1 of strontia, and 3 of water. (Thomson.)

Tartrate of Magnesia is precipitated from the sulphate by tartaric acid: it is soluble in excess of tartaric acid, and forms a crystallizable salt. When dried at 60°, it consists of one proportional of anhydrous tartrate, and two of water. There is also a *bitartrate of magnesia.* (Thomson.)

Tartrate of Manganese, formed by dissolving protoxide of manganese in tartaric acid, is a soluble salt, and therefore not immediately precipitated by adding tartaric acid, or a neutral tartrate, to protochloride or protosulphate of manganese. When hot solutions of protochloride of manganese and tartrate of potassa are mixed, small crystals are deposited on cooling, which are resolved by boiling water into a soluble supertartrate and an insoluble basic salt. (Pfaff.) The crystals consist of ($tar'+\text{Man}+2q.$) Thomson. When the protosalts of manganese are mixed with tartar the oxide is not thrown down by pure or carbonated alkalis. (H. Rose.) When tartaric acid and peroxide of manganese are boiled together in water, carbonic acid is evolved, and a colourless solution of prototartrate of manganese is obtained. Formic acid is also produced during the action of the acid and oxide. (*Quarterly Journal*, xiv., 232.)

Tartrates of Iron. Tartaric acid acts upon soft iron with the disengagement of hydrogen gas, and a difficultly-soluble *prototartrate* of iron, nearly white, and pulverulent, is formed. At a dull red-heat, this tartrate readily takes fire, and burns slowly away like tinder, the iron becoming peroxidized. It will probably form a valuable addition to the *Materia Medica.* (Ure, *Quarterly Journal*, *Oct.*, *Dec.*, 1829.) When hot and strong solutions of tartaric acid and protosulphate of iron are mixed, white foliated crystals of *prototartrate of iron* are deposited on cooling: this salt requires 400 parts of cold water for solution. (Dumas.) It has a slightly inky taste, and consists of ($tar'+\text{Fe}+2q.$) (Thomson.)

Tartaric acid has scarcely any action upon the red oxide of iron, but a *pertartrate of iron* may be obtained by mixing the liquid red sulphate of iron with tartrate of potassa, in equivalent proportions. Sulphate of potassa precipitates in a crystalline powder, (the solutions being sufficiently concentrated,) which may be separated from the blood-red liquid pertartrate of iron by filtration. Alcohol forms a treacly precipitate in this solution.

Tartrate of Iron and Potassa. When 1 part of iron-filings and 4 of tartar are digested together with water, a greenish, astringent, and difficultly-soluble salt is formed: it is not decomposed by pure or carbonated alkalis, but by sulphuretted hydrogen. (Thenard.) By long exposure of the mixture of tartar and iron to air, or by mixing 1 part of soft iron-filings with 4 of tartar into a thin paste with water, and digesting for some weeks, till the acid is neutralized, fresh portions of water being occasionally added to prevent exsiccation, a dark-brown uncrystallizable compound is obtained, the solution of which has been used in medicine. It is not decomposed by the alkalis. The pertartrate of iron and potassa is best obtained by digesting recently-precipitated hydrated peroxide of iron with bitartrate of potassa and water. It dissolves in alcohol.

Tartrate of Zinc is formed by adding tartrate of potassa to sulphate of zinc, and is a very difficultly soluble compound. When oxide of zinc is dissolved with tartar the solution is not affected by the alkalis, but their sulphurets throw down the whole of the zinc.

Tartrate of Tin. Tartrate of potassa occasions a white precipitate in the neutral protomuriate and permuriate of tin. *Tartrate of potassa and tin*, formed by boiling the oxide in solution of tartar, is very soluble; the addition of alkalis and their carbonates occasions no precipitates. (Thenard, *Ann. de Chim.*, xxxviii.)

Tartrate of Copper is produced by adding tartaric acid to sulphate of copper. It forms a blueish-green crystallized precipitate. When tartaric acid is added to a solution of the neutral tartrate, a more difficultly soluble *bitartrate* falls.

Tartrate of Potassa and Copper is formed by boiling hydrated oxide of copper and tartar in water; the solution yields blue crystals on evaporation; or if boiled to dryness, furnishes one of the pigments called *Brunswick-green.*

Tartrate of Lead is thrown down in the form of an almost insoluble white crystalline powder, on adding tartaric acid to solution of nitrate or acetate of lead: it is soluble in excess of carbonic acid. When this tartrate is heated to a dull-red in a glass tube, it acquires a brown colour; and, when cool, forms, as was first remarked by Dr. Gobel, a very perfect *pyrophorus*, which immediately inflames on being shaken out into the air. This property appears to depend upon the rapid oxidizement of the minutely-divided metallic lead; or, perhaps, a very oxidizable carburet of lead may be formed. Tartrate of lead is composed of

				Berzelius.	Thomson.	Bucholz.
Oxide of lead	1	112	62.92	62.5	62.56	63
Tartaric acid	1	66	37.08	37.5	37.44	37
	1	178	100.00	100.0	100.00	100.

Tartrate of Potassa and Lead is formed, according to Thenard, by boiling a mixture of tartar and oxide of lead in water. (*Ann. de. Chim.*, xxxviii.) It is an insoluble white powder, not decomposed by the alkalis or sulphuric acid.

Tartrate of Antimony. Protoxide of antimony dissolved in tartaric acid yields a very soluble, deliquescent, and difficultly-crystallizable salt.

Tartrate of Antimony and Potassa; Emetic Tartar. This compound may be obtained by boiling protoxide of antimony, obtained by any of the processes formerly described, with pure supertartrate of potassa. Emetic tartar is usually prepared by boiling a solution of 100 parts of tartar with 100 parts of *finely levigated* glass of antimony (or other *protoxide*); the ebullition should be continued for half an hour, and the filtered liquor evaporated to about half its bulk, and set aside to crystallize; octoëdral crystals (Brooke, *Ann. of Phil.*, *N. S.*, vi., 40) of the emetic salt are thus obtained; and there is generally formed along with them a portion of tartrate of lime and potassa, which is deposited in small radiated tufts, easily separated when the mass is dried.

Emetic tartar is a white salt, slightly efflorescent, soluble in about 14 parts of cold, and 2 parts of boiling water. Its solution is rendered turbid by muriatic, nitric, and sulphuric acids, but not by the fixed alkalis: the fixed alkaline carbonates and lime-water decompose it. Infusion of galls and many other vegetable bitter and astringent infusions form a precipitate in solution of emetic tartar, which is generally said to be inactive, and hence decoction of bark has been recommended as an antidote to its effects. Solution of sulphuretted hydrogen only precipitates very strong solutions of emetic tartar; weaker solutions are merely reddened by it. It is decomposed by hydrosulphuret of ammonia: among the metals, iron only throws down the whole of its antimony. At 212° the crystals lose about 2 *per cent.* of water; at a higher temperature about 7 or 8 *per cent.* Heated to redness, out of the contact of air, it furnishes a highly-pyrophoric residue. This salt (crystallized) consists of

				Wallquist.	R. Phillips.
Protoxide of antimony	2	154	42.6	42.99	43.35
Potassa	1	48	13.3	13.26	49.25
Tartaric acid	2	132	36.6	38.61	
Water	3	27	7.5	5.14	7.40
	1	361	100.0	100.00	100.00

Tartrate of Bismuth has not been examined, but moist oxide of bismuth, boiled with tartar, forms a difficultly-soluble triple salt.

Tartrate of Cobalt. Tartrate of potassa forms no precipitate in solutions of cobalt, but their colour is much heightened by it. Moist oxide of cobalt is soluble in tartaric acid, and the solution furnishes red crystals on evaporation.

Tartrate of Uranium is a very soluble salt, not easily crystallizable.

Tartrate of Titanium appears to be a soluble compound.

Tartrate of Cerium, according to Hisinger and Berzelius, is formed by adding tartrate of potassa to sulphate, nitrate, or muriate of cerium. It is a soft, tasteless powder, soluble in nitric, muriatic, and sulphuric acids, and in the alkalis.

Tartrate of Nickel, formed by digesting moist oxide of nickel in tartaric acid, is a very soluble salt; tartaric acid occasions no precipitate in the soluble salts of nickel.

Tartrate of Mercury. Tartaric acid occasions white precipitates in all the solutions of the oxides of mercury, not containing excess of acid.

Tartrate of Potassa and Mercury is formed, according to Thenard, by adding solution of tartar to protonitrate of mercury; and an analogous salt of the peroxide may be obtained by boiling it in a solution of tartar.

Tartrate of Silver. Tartaric acid occasions no change in nitrate of silver, but tartrate of potassa forms a white precipitate, which is probably a tartrate of silver.

Tartrate of Silver and Potassa is thrown down by adding tartar to nitrate of silver.

Tartrate of Silver and Antimony. The precipitate which falls on adding nitrate of silver to a solution of emetic tartar, consists of

				Wallquist.
Oxide of Silver	1	118	28.0	27.31
Protoxide of antimony	2	154	36.5	36.94
Tartaric acid	2	132	31.3	31.50
Water	2	18	4.2	4.25
	1	422	100.0	100.00

Tartrate of Alumina is a soluble uncrystallizable compound of an astringent flavour: it is not deliquescent. It exists in the *Lycopodium complanatum*, an infusion of which may be used as a mordant.

II. **Oxalic Acid.** This acid, which was discovered by Scheele, is found in some fruits, and in considerable quantity in the juice of the *Oxalis acetosella* or *wood-sorrel*, in the *Rumex acetosa* or *common sorrel*, and in the varieties of *rhubarb*. It is most readily procured by the action of nitric acid on certain organic substances, and especially upon sugar, and has hence been termed *acid of sugar*. It may be obtained by introducing into a retort, 4 ounces of nitric acid diluted with 2 of water, and 1 ounce of white sugar; nitric oxide gas is copiously evolved, and when the sugar is dissolved, about one-third of the acid may be distilled over: the contents of the retort are then emptied into a shallow vessel, and in the course of two or three days an abundant crop of white crystals is deposited, and, upon further evaporation of the mother-liquor, a second portion is obtained. The whole crystalline produce is to be redissolved in water, and again crystallized, by which the pure acid is obtained. In this way sugar yields rather more than half its weight of oxalic acid.

Oxalic acid thus procured is in the form of four-sided prisms, transparent, and of a very acid taste; their primary form is a right rhombic prism, the modifications of which have been described by Mr. Brooke. (*Ann. of Phil.*, *N. S.*, vi. 119.) The crystals dissolve in about 15 parts of water at 50°, and in 9 parts at 60°, their solubility increasing rapidly with the increase of temperature; at 212°, they fuse in their water of crystallization. The great solubility attributed to this acid by Bergman, seems to have depended upon the presence of nitric acid. It is less soluble in alcohol than in water. In a very dry air the crystals effloresce; at a temperature of 100°, they gradually fall into a white powder, and when thus slowly dried lose about a third of their weight. As this acid is volatile, its desiccation requires much caution: the crystals after having been deprived of 2 equivalents of water, sublime rapidly when heated to about 330°; the sublimate forms transparent acicular crystals, containing 1 atom of water; they absorb moisture, and become opaque by exposure to air. When the ordinary crystals are rapidly heated in a retort to about 300°, water, carbonic acid, carbonic oxide, and formic acid are the results. Passed through a red-hot tube, carbonic oxide and acid, and carburetted hydrogen are evolved, and a little charcoal, with a trace of oily matter is deposited. Muriatic acid dissolves oxalic acid without decomposition. Mixed with about 20 parts of sulphuric acid, and gently heated, it is rapidly resolved into equal volumes of carbonic acid and carbonic oxide, which gases are evolved, whilst the water of the crystals remains combined with the sulphuric acid. Oxalic acid absorbs chlorine, and the resulting compound is resolved by the action of water into muriatic and carbonic acids. (*Ann. de Chim. et Phys.*, xix. 84.) The intensity of the acidity of oxalic acid is such, that one part in 200.000 of water reddens litmus. It abstracts lime from sulphuric acid when added to a solution of sulphate of lime, but oxalate of lead is decomposed by sulphuric acid, so that its affinity for bases appears to be about equal to that of sulphuric acid. It is extremely poisonous, and many accidents have occurred from its resemblance in external appearance to Epsom salt (sulphate of magnesia) and from the carelessness with which medicines are often dispensed and taken. The intense sourness of oxalic acid, and the saline bitterness of the sulphate, readily distinguish them; chalk or whiting, or magnesia or carbonate of magnesia, or large draughts of soap and water, are the most ready antidotes.

The composition of oxalic acid, is a subject which has engaged much attention, since Döbereiner first suggested the non-existence of hydrogen as one of its ultimate elements, and showed that in its *anhydrous* state, as it exists in combination with certain bases, as for instance, with oxide of lead, it might be regarded as a binary compound of carbon and oxygen. Its equivalent, founded upon this view, is 36, and it consists of $({}_{2}car + {}_{3}O)$ or,

Carbon	2	12	33.33	or	Carbonic oxide	1	14	38.8
Oxygen	3	24	66.66		Carbonic acid	1	22	61.2
	1	36	100.00			1	36	100.0

The *ordinary crystals* contain

				Berzelius.	Prout.
Anhydrous oxalic acid	1	36	57.14	58	57.15
Water	3	27	42.86	42	42.85
	1	63	100.00	100	100.00

And the crystals, dried as far as possible without decomposition, by which they lose about 28 *per cent.* of water, leave a compound of

				Berzelius.
Anhydrous oxalic acid .	1	36	80	80.5
Water	1	9	20	19.5
	1	45	100	100.0

Those who consider an atom of water as an essential component of the dry oxalic acid, represent it by the equivalent 45, and regard the acid as a compound of

Carbon	2	12	26.66
Oxygen	4	32	71.10
Hydrogen	1	1	2.24
	1	45	100.00

Oxalate of Ammonia. This curious salt is generally obtained by saturating a solution of oxalic acid by ammonia, and crystallizing. It forms prismatic crystals, (Brooke, *Ann. of Phil.*, *N. S.* vi., 374,) of which 45 parts require 1000 of cold water, for their solution. They are much more soluble in hot water. Added to any soluble compound of lime, this salt produces an insoluble *oxalate of lime*, provided no excess of acid be present; hence its use as a test of the presence of lime in water. The crystals are insoluble in alcohol. They contain two equivalents of water, one of which may be expelled by heat, when they crumble into a white powder, composed of

				Berzelius.	Berard.	Thomson.
Ammonia	1	17	27.42	26.88	27.66	25.55
Oxalic acid	1	36	58.07	59.37	72.34	74.45
Water	1	9	14.51	13.75		
	1	62	100.00	100.00	100.00	100.00

Binoxalate of Ammonia, ($2\,Ox' + A$,) is less soluble than the oxalate; it consists of two proportionals of acid, one of ammonia, and two of water (Berard), eight of water. (Dumas.)

Oxamide. Oxalamide. When oxalate of ammonia is distilled, it becomes opaque from loss of water, fuses, boils, decomposes and volatilizes, leaving a little carbon behind; the liquid which passes over contains a flocculent substance, which also lines the neck of the retort, and to which M. Dumas has given the name of *oxalamide;* it may be separated by washing and filtration, 100 parts of the oxalate yielding about 5. The other products are ammonia, water, carbonic acid, carbonic oxide, and cyanogen. Oxamide is in imperfect crystallized plates, or a granulated powder, without taste or smell, and having no action on test-papers. It is volatile when carefully heated, but generally sublimes with more or less decomposition, yielding cyanogen and carbon: it is scarcely soluble in water at 60°, and a saturated solution at 212° deposits it in crystalline flocculi. It is insoluble in alcohol. It is composed of

			Dumas.
Carbon	2	12	27.4
Oxygen	2	16	36.3
Hydrogen	2	2	4.5
Nitrogen	1	14	31.8
	1	44	100.0

Consequently oxamide differs from oxalate of ammonia in containing less water, by two atoms; for 44 oxamide + 18 water = 62 oxalate of ammonia; and oxamide may, under certain circumstances, resume this elementary water, as by the action of acids or hydrated alkalis aided by heat. Boiled for instance with potassa, or soda, oxamide evolves ammonia, and the carbon and oxygen remain in the state of oxalic acid: the dilute sulphuric, nitric, and muriatic acids convert oxamide into oxalic acid, and become ammoniacal salts. Boiled with concentrated sulphuric acid, oxamide affords sulphate of ammonia, and equal volumes of carbonic acid and carbonic oxide are disengaged: concentrated nitric acid converts oxamide into nitrate of ammonia and carbonic acid. In these cases, oxamide, by decomposing an atom of water, furnishes oxalic acid and ammonia, or

$$\text{Oxamide}\left\{\begin{array}{l}\left.\begin{array}{ll}\text{Carbon} & .\ 2\\ \text{Oxygen} & .\ 2\end{array}\right\}+1\text{ Oxygen}\left\{\text{Oxalic acid}\right.\\ \left.\begin{array}{ll}\text{Hydrogen} & .\ 2\\ \text{Nitrogen} & .\ 1\end{array}\right\}+1\text{ Hydrogen}\left\{\text{Ammonia}\right.\end{array}\right.\left.\vphantom{\begin{array}{l}a\\b\\c\\d\end{array}}\right\}\begin{array}{l}\text{Oxalate of}\\ \text{Ammonia.}\end{array}$$

The elements of oxamide, as will be seen by the above diagrams, are such as to represent 2 atoms of carbonic oxide + a compound of 2 atoms of hydrogen and 1 of nitrogen; now it has been ingeniously suggested by Dumas that an analogy subsists between this bihydruret of nitrogen, and the bicarburet of nitrogen or cyanogen, and that both resemble the haloid bases; that is, considering $\overline{n + 2\,h}$, which we may call *ammogen*, as a compound analogous to cyanogen, oxamide would be a compound analogous to the cyanurets and chlorides. We shall afterwards have occasion to revert to this analogy, in the mean time, it may be observed that the elements of oxamide are such as to admit of other hypothetical distributions; that they are for instance equivalent to nitrous oxide and olefiant gas $(n + 2\,o) + (2\,h + 2\,car)$ or to cyanogen and water, $(n + 2\,car) + 2.(h + o)$. Compounds of the base $n + 2\,h$ with other acids are also distinguished by the termination *amide*, as *benzamide*, *succinamide*, &c.

Oxalate of Potassa $(Ox' + \mathrm{P})$ forms flat rhomboidal crystals, soluble in rather less than 3 parts of water at 60°: the crystals include one proportional of water. The greater number of vegetable substances, such as cotton, wood, sugar, starch, gum, and most of the acids, and some animal substances, are converted into oxalic acid when fused with from four to six times their weight of caustic potassa, at a temperature below that which occasions charring: in this way *oxalate of potassa* is produced, and is converted, at a higher temperature, into carbonate of potassa.

Binoxalate of Potassa. $(2\,Ox' + \mathrm{P}.)$ Oxalate of potassa, dissolved in oxalic acid, produces the *binoxalate*, which crystallizes in small rhombic crystals of a bitterish and sour taste, soluble in about 10 parts of cold water. This salt, together with the quadroxalate, exists ready formed in the juice of the *Oxalis acetosella*, and is known under the name of *salt of wood-sorrel.*

Quadroxalate of Potassa, $(4\,Ox' + \mathrm{P})$. When binoxalate of potassa is digested in nitric or muriatic acid, half the potassa is abstracted and a *quadroxalate* remains. The crystals of this salt include seven proportionals of water: or, according to Berard, only three. The composition of these several oxalates of potassa was originally pointed out by Wollaston, and deserves to be recorded as the first well-authenticated illustration of the theory of multiple proportionals. (*Phil. Trans.*, 1808.)

Ammonio Oxalate of Potassa. When the binoxalate of potassa is neutralized by an atom of ammonia, a double salt, which forms long, permanent, acicular crystals, is obtained.

Oxalate of Soda is sparingly soluble in water, and separates from its solution in small crystalline grains, composed of

				Berard.	Thomson.
Soda . .	1	32	41.6	41.08	36.37
Oxalic acid	1	36	46.8	58.92	63.63
Water .	1	9	11.6		
	1	77	100	100.00	100.00

There is a *binoxalate*, but apparently no *quadroxalate* of soda.

Oxalate of Lithia is difficultly crystallizable and very soluble. The *binoxalate* forms small transparent granular crystals, not so soluble as the neutral salt.

Oxalate of Lime. ($Ox'+C$.) This compound exists in many plants, and the little transparent bodies called *raphides*, found in the cellular tissue, and floating occasionally in their juices, as in the sap of very old trees, and in the juice of the common hyacinth, are composed, according to Raspail, of this salt. Oxalate of lime also exists occasionally in the human urine, and forms calculi of the kidney and bladder, which, from their rough or nodular exterior and brown colour, are generally called *Mulberry calculi.* It may be formed artificially by adding oxalic acid or oxalate of ammonia to any solution of lime. It is insoluble in water, and in excess of oxalic acid, but dissolves in muriatic and nitric acids: hence in testing *acid solutions* for lime, by oxalic acid, or oxalate of ammonia, the excess of acid should be previously neutralized. Whilst drying upon the sand-heat this salt becomes singularly electrical. At a red-heat it is converted first into carbonate, and then into quicklime. When recently precipitated, well washed, and dried by mere exposure to air, it consists of

				Thomson.
Lime	1	28	34.1	33.98
Oxalic acid	1	36	43.9	43.69
Water	2	18	22.0	22.33
Dried at 60°	1	82	100.0	100.00

When kept at 212°, till it no longer loses weight, it appears to consist of

				Vogel.	Berard.	Gay-Lussac and Thenard.
Lime	1	28	38.3	38.5	38	38.655
Oxalic acid	1	36	49.3	49.5	62	61.345
Water	1	9	12.4	12.0		
Dried at 212°	1	73	100.0	100.0	100.	100.000

When dried at 500°, it becomes *anhydrous*, and then contains

				Vogel. Thomson.	Dumas.
Lime	1	28	43.7	43.75	44.01
Oxalic acid	1	36	56.3	56.25	55.99
Dried at 500°	1	64	100.0	100.00	100.00

As oxalate of lime is frequently referred to in quantitative analysis, the degree of desiccation must be, in such cases, attentively observed; but it is perhaps better to convert it by heat and sulphuric acid into *anhydrous sulphate of lime*, the equivalent of which is more certain.

Oxalates of Baryta is very nearly insoluble. It cannot be obtained in an anhydrous state, but when dried at 212°, contains

				Berard.
Baryta	1	77	63.0	62.17
Oxalic acid	1	36	29.5	37.83
Water	1	9	7.5	
	1	122	100.0	100.00

Binoxalate of Baryta is formed by boiling excess of oxalic acid with carbonate or nitrate of baryta; on cooling it is deposited in transparent crystals. Boiling water resolves these into a precipitate of neutral oxalate, and free acid. The crystals contain

				Berard.
Baryta	1	77	46.5	45
Oxalic acid	2	72	43.5	55
Water	2	18	10.0	
	1	167	100.0	100

Oxalate of Strontia is a white tasteless powder nearly insoluble in water (in 1920 boiling water, Hope.) It consists of 1 atom of oxalic acid, 1 of strontia, and 2 of water. (Thomson.)

Oxalate of Magnesia is a white, tasteless, and almost insoluble powder; yet it is not immediately thrown down when oxalic acid, or even oxalate of ammonia, is added to sulphate of magnesia, unless the solutions are concentrated and hot. Hence oxalate of ammonia may be used to detect lime in solutions containing magnesia.

Oxalate of Manganese. When black oxide of manganese and superoxalate of potassa are triturated together and moistened, carbonic acid is evolved; and, on adding more water, and filtering, a red solution, containing oxalic acid, potassa, and manganesic acid, is obtained, which after a time becomes colourless, and a triple salt is formed, containing the protoxide of manganese. Oxalic acid and oxalate of ammonia throw down a white powder from concentrated solutions of the protosalts of manganese.

Oxalate of Iron. The *protoxalate* crystallizes in green prisms, and may be formed either by digesting the metal, or dissolving the protoxide in the acid. The *peroxalate* is thrown down from the permuriate or persulphate of iron, in the form of a difficultly-soluble yellow powder, which is taken up again by excess of oxalic acid: hence the use of this acid in removing iron-moulds, which it does without injuring the texture of linen.

Oxalate of Zinc is formed by adding oxalic acid to a soluble salt of zinc: it is a white powder, nearly insoluble.

Oxalate of Tin is formed, according to Bergman, by digesting the metal in the acid; the solution, slowly evaporated, gives prismatic crystals.

Oxalate of Cadmium is a white insoluble powder.

Oxalate of Copper. Oxalic acid oxidizes and dissolves copper. When oxalic acid is added to sulphate or nitrate of copper, *oxalate of copper* is thrown down in the form of a green powder, soluble in excess of acid, and yielding a solution from which prismatic green crystals may be obtained, of binoxalate?

Oxalate of Copper and Ammonia. This, and several other *double oxalates of copper*, have been described by Vogel. (Schweigger's *Journal*, vii.) By digesting oxalate of copper in a solution of oxalate of ammonia, and filtering, rhomboidal crystals were obtained on evaporation, which detonated when suddenly heated: when slowly heated, they merely lost water and ammonia. From the analysis of this salt, it appears to consist of

				F. C. Vogel.
Ammonia . .	1	... 17	... 10.90	... 10.5
Oxide of Copper	1	... 40	... 25.64	... 25.0
Oxalic acid . .	2	... 72	... 46.15	... 47.5
Water . . .	3	... 27	... 17.31	... 17.0
	1	156	100.00	100.0

By digesting oxalate of copper in caustic ammonia, and pouring the solution thus obtained into a shallow basin, it deposits flat six-sided prisms of a blue colour, which effloresce on exposure to air. The undissolved portion of the oxalate also combines with ammonia, and produces another distinct compound.

Oxalate of Copper and Potassa is obtained by digesting carbonate of copper in solution of binoxalate of potassa. Prismatic and rhomboidal crystals are formed, which Vogel considers as two distinct salts; the former, consisting of one proportional of oxalate of copper, one of oxalate of potassa, and *eight* of water; and the latter, of one proportional of oxalate of copper, one of oxalate of potassa, and *two* of water.

Oxalate of Copper and Soda. Vogel has also described two varieties of this salt. (Schweigger's *Journal*, vii.)

Oxalate of Lead ($Ox' + \mathrm{Pl}$) is thrown down in crystalline grains on adding oxalic acid to nitrate of lead. It is insoluble in water, but dissolves sparingly in excess of oxalic acid. Heated in close vessels it leaves a suboxide of lead; in the air it leaves oxide of lead: it is anhydrous when dried at 212°, and consists of

				Berzelius.
Oxide of lead	1	... 112	... 75.68	... 75.46
Oxalic acid	1	... 36	... 24.32	... 24.54
	1	148	100.00	100.00

When heated in a tube with potassium, it detonates violently.

Oxalate of Antimony has not been examined.

Oxalate of Bismuth is deposited in crystalline grains, when solution of oxalic acid is dropped into nitrate of bismuth.

Oxalate of Cobalt is an insoluble red powder, precipitated by oxalic acid from solutions of cobalt. It dissolves in excess of oxalic acid, and the solution furnishes crystals. The dry salt yields, when heated in a tube, 0.3286 metallic cobalt, 0.4757 carbonic acid, and 0.1957 water; it therefore consists of 1 atom of oxide of cobalt, 1 of oxalic acid, and 2 of water. When carefully heated, it loses water, and then burns in the air. (Döbereiner.) It forms a double salt with oxalate of ammonia.

Oxalate of Uranium is difficultly soluble in water, and is precipitated by concentrated oxalic acid from the neutral salts of uranium. A weak solution of a salt of uranium is not disturbed by oxalate of potassa. The oxalate of uranium contains 13.5 *per cent.* water, the oxygen of which is to that of the oxide as 3 : 1. (Berzelius.)

Oxalate of Cerium is precipitated by the addition of oxalic acid or oxalate of ammonia to solutions of the protoxide of cerium, of a white colour, insoluble in excess of acid, but soluble in liquid ammonia. In solutions of the peroxide of cerium, the precipitate is of a dingy-red, and soluble in ammonia.

Oxalate of Nickel is thrown down from the nitrate in the form of an insoluble green powder. It contains 13.4 *per cent.* (= 2 atoms) of water: heated in a retort it yields carbonic acid and metallic nickel: it forms double salts with the oxalates of ammonia, potassa, and soda.

Oxalate of Chromium, in solution, is red by transmitted, and green by reflected, light; it yields, on evaporation, a green deliquescent and very soluble salt, which crystallizes with excess of acid, and is not precipitated by, but forms double salts with, the alkalis.

Oxalate of Molybdenum. The *protoxalate* is dark-gray; black when dry; and little soluble in excess of oxalic acid. The *peroxalate* may be obtained in very dark-blue crystals, yielding a red solution from which ammonia throws down a red *basic* salt, insoluble in excess of ammonia. Molybdic acid yields a colourless solution in oxalic acid, which, when evaporated, becomes at first gelatinous, and then crystalline; it is soluble in water and alcohol. These oxalates of molybdenum all yield double salts with oxalate of potassa. (Berzelius.)

Oxalate of Titanium falls as a curdy hydrated precipitate, when a solution of titanium is heated with oxalic acid: it dissolves in excess of acid, and consists, according to Rose, of 6 atoms of oxide of titanium, 1 of oxalic acid, and 6 of water.

Oxalate of Columbium. According to Wollaston, the recently-precipitated hydrated columbic acid dissolves in oxalic acid; but Gahn, Berzelius, and Eggertz state, that only a trace of the acid is so dissolved, but that binoxalate of potassa readily takes it up and forms with it a double salt, from which the alkalis throw down columbic acid.

Oxalate of Mercury is precipitated from the nitrates by oxalic acid. The *protoxalate* is scarcely soluble, and detonates slightly when heated. It was supposed to exist in Howard's fulminating mercury, but this appears not to be the case. It forms a double salt with oxalate of potassa.

Oxalate of Silver is an insoluble white powder, which blackens when exposed to light. It is precipitated on adding oxalic acid to nitrate of silver, and is soluble in nitric acid. It detonates slightly when violently struck upon an anvil: when heated it becomes electric, and evolves water and carbonic acid, leaving metallic silver. It forms a double salt with oxalate of potassa.

Oxalate of Alumina is easily formed by dissolving the newly-precipitated earth in oxalic acid: it does not crystallize, but affords, on evaporation, a gelatinous mass, which deliquesces on exposure. This is probably a binoxalate, for Berzelius states that the neutral oxalate is insoluble.

Hydroxalic Acid. (*Acide oxalhydrique.*) Under this name Guérin-Varry (*Ann. de Chim. et Phys.*, lii., 318) has described a peculiar acid, which is formed, together with oxalic acid, during the action of nitric acid upon sugar, gum, and other substances, and which was noticed by Scheele, and considered as identical with malic acid. Guérin obtains this acid by mixing one part of gum-arabic with two of nitric acid, diluted with half its weight of water in a retort of four times the capacity of that of the mixture, and connected with a tubulated receiver: heat is applied till nitrous vapours begin to appear; it is then withdrawn, and a large quantity of nitrous gas succeeds; when this ceases, the liquor is boiled for an hour, then diluted with 4 parts of water, saturated by ammonia, and a solution of nitrate of lime is then added to precipitate oxalic acid: the solution, which is now of an orange-colour, is filtered and precipitated by acetate of lead: the precipitate is washed upon a filter till the washings no longer are discoloured by sulphuretted hydrogen, and is then decomposed either by a stream of that gas or by sulphuric acid diluted with 6 weights of water: the acid thus obtained is evaporated by a gentle heat, and, when sufficiently concentrated, is neutralized by ammonia, and evaporated till it begins to crystallize. The crop of crystals which it affords, and which are dark-coloured, are dissolved and treated by animal charcoal, the decoloured solution is then precipitated again by acetate of lead, and the precipitate decomposed as before: the acid liquor now obtained is cautiously evaporated to the consistency of syrup, and the evaporation is completed in vacuo, till the residuary liquor begins to acquire a yellow tint.

Trommsdorf's process, for obtaining this acid, is as follows: He heats a mixture of equal parts of sugar and nitric acid (specific gravity 1.2) till it begins to effervesce; abundance of gas is evolved, and the liquid becomes thick and yellow; it is then diluted with water, and saturated by chalk, the excess of which, and the precipitated oxalate of lime, are removed by filtration: the filtered liquor is concentrated by evaporation and mixed with alcohol, which precipitates the *hydroxalate of lime:* this is collected, redissolved, filtered through charcoal, and decomposed by acetate of lead; the resulting *hydroxalate of lead* is decomposed as before by sulphuretted hydrogen: to get it colourless, the acid must be saturated by soda, again thrown down by lead, and this decomposed as before. Eight ounces of sugar yield about one ounce of the acid. (*Ann. de Chim. et Phys.*, liv. 208.)

Hydroxalic acid, when obtained in its utmost state of concentration, is in the form of a syrupy, colourless, inodorous, and intensely-sour liquid. Its specific gravity is 1.415 at 60°. It unites in all proportions with water and alcohol, but is only sparingly soluble in ether. It is very deliquescent. It precipitates lime, baryta, and strontia water, and the precipitates are all soluble in excess of acid: in this respect it resembles tartaric acid; but it differs from that acid in not precipitating potassa or its salts when added to them in excess: it is distinguished from malic acid, which does not precipitate the above bases. It furnishes copious white precipitates in solutions of lead and silver. It dissolves zinc and iron, with disengagement of hydrogen, but has no action on tin. When 1 part of hydroxalic acid and 3 of nitric acid are mixed and left for a month, at common temperature, being shaken daily, nitrous gas and carbonic acid are evolved, and crystallized oxalic acid formed: boiled with nitric acid, hydroxalic acid is converted into oxalic and carbonic acids: with equal parts of sulphuric acid and water, it yields sulphurous and carbonic acids: it is changed into formic acid when gently heated with sulphuric acid and black oxide of manganese. Subjected to destructive distillation it affords the usual products of these compounds, and leaves a bulky charcoal.

According to Guérin, this acid, in its *anhydrous* state, as in the salt of lead, is composed of $(4\ car + 3\ h + 6\ o)$: its equivalent, therefore, is 75; or,

				Guérin.
Carbon	4	24	32	32.4
Hydrogen	3	3	4	3.9
Oxygen	6	48	64	63.7
Anhydrous hydroxalic acid	1	75	100	100.0

The above numbers are, it is to be observed, equivalent to 2 atoms of dry oxalic acid + 3 atoms of hydrogen.

III. Citric Acid. This acid exists in many vegetables, either free, or combined with lime: it is especially abundant in *lemon-juice*, from which it was first obtained in a crystalline form by Scheele: it is contained in gooseberries, raspberries, and other fruits, and is often associated with malic acid.

Citric acid is obtained from lemon or lime-juice as follows. Boil the expressed juice for a few minutes, and, when cold, strain it through fine linen: then add powdered chalk as long as it produces effervescence; heat the mixture, and strain as before: a quantity of *citrate of lime* remains upon the strainer, which, having been washed with cold water, is to be put into a mixture of sulphuric acid with 20 parts of water: the proportion of acid may be about equal to that of the chalk employed. In the course of 24 hours, the citrate of lime will have suffered decomposition, and sulphate of lime is formed, which is separated by filtration. The filtered liquor, by careful evaporation, as directed for tartaric acid, furnishes crystallized citric acid.

The preparation of this acid is carried on by a few manufacturers upon an extensive scale; in different states of purity, it is employed by the calico-printers, and used for domestic consumption. Many circumstances which have not here been alluded to, are requisite to ensure complete success in the operation; these have been fully described by Mr. Parkes, in the third volume of his *Chemical Essays*. The average proportion of citric acid afforded by a gallon of good lemon-juice, is about eight ounces. Dr. Henry states that he has obtained as much as twelve ounces.

Citric acid forms beautiful crystals, of which the primary form is a right rhombic prism. They have a very sour taste, and are soluble in somewhat less than their own weight of water at 60°, and in half their weight at 212°. They also dissolve in alcohol.

M. Tilloy of Dijon, recommends gooseberries as a source of citric acid: they are bruised, and the expressed juice is fermented, and then distilled to obtain the alcohol: the residue is saturated by chalk, and the washed citrate of lime decomposed by sulphuric acid: from 100 parts of gooseberries he obtained 10 of alcohol and 1 of acid.

Citric acid is sometimes fraudulently mixed with the tartaric: the adulteration may be discovered by gradually adding to the acid dissolved in water, a solution of carbonate of potassa, which will occasion the precipitation of bitartrate of potassa if tartaric acid be present.

The crystals of citric acid include a certain proportion of water, part of which may be expelled by heat: in its *anhydrous* state, as it exists combined with certain bases, it is a compound of

				Berzelius.
Carbon	4	24	41.38	41.369
Hydrogen	2	2	3.45	3.800
Oxygen	4	32	55.17	54.831
Anhydrous citric acid	1	58	100.00	100.000

Hence we have the equivalent of this acid 58, (58.48, Turner; 58, Gmelin); or $(4\,car + 2\,h + 4\,o.)$

The *crystals* of citric acid, *deposited from its saturated solution* at 212°, contain 1 atom of water: they are, therefore, represented by the symbol $(4\,car + 2\,h + 4\,o + q)$, or $(cit' + q.)$ Their equivalent is $58 + 9 = 67$, and they include

				Dumas.	Prout.	Ure.
Carbon	4	24	35.8	36.28	34.28	33.00
Hydrogen	3	3	4.6	4.45	4.76	4.63
Oxygen	5	40	59.6	59.27	60.96	62.37
Crystallized citric acid	1	67	100.0	100.00	100.00	100.00

These crystals fuse at a little above 212°, into a limpid liquid, without loss of weight, and concrete, on cooling, into a solid transparent mass. The crystals which are obtained by the *spontaneous evaporation*, at common temperatures, of a solution of citric acid, differ in composition from the former, and contain 3 atoms of anhydrous acid and 4 of water $(3\,cit' + 4\,q)$, which, therefore, is the composition of the ordinary citric acid of commerce; or,

				Berzelius.
Anhydrous citric acid	1	58	82.86	83
Water	$\frac{4}{3}$	12	17.14	17
Common crystallized acid	1	70	100.00	100.

These crystals are permanent at common temperatures, but when dried at 212° they effloresce and lose exactly half their weight of water, being reduced to $(3\,cit + 2\,q)$, or

				Berzelius.
Anhydrous citric acid	1	58	90.6	90.7
Water	$\frac{2}{3}$	6	9.4	9.3
Effloresced citric acid	1	64	100.0	100.0

When any attempt is made to drive off more water by the application of a higher temperature, the acid is itself decomposed.

CITRATES. The *neutral* citrates, considered as compounds of anhydrous citric acid and bases, are so constituted that the oxygen in the acid is to that in the base as 4 to 1. Many of them are insoluble, or difficultly soluble, but are soluble in excess of acid: those which are soluble do not deposit difficultly-soluble acid citrates, when excess of acid is added. When cold, they give scanty precipitates with the salts of lime, but copious when heated: these precipitates are soluble in a large quantity of water, and in acetic acid. Some of the peculiarities of the citrates have been pointed out by Berzelius. (*Ann. de Chim. et Phys.*, lii., 424 and 432.)

CITRATE OF AMMONIA crystallizes with difficulty in prisms.

CITRATE OF POTASSA is very soluble, deliquescent, and difficultly crystallizable. It is much used in medicine as a mild diaphoretic, and is the *Salt of Riverius* of old pharmacy. 76 parts of the crystallized acid saturate 70 of carbonate of potassa.

Citrate of Soda is crystallizable in prisms, of a saline flavour, and soluble in somewhat less than their weight of cold water. When this salt is dried at 212° it loses 17.5 *per cent.* of water, and the remaining salt is a compound of $(cit' + S + q.)$ Berzelius conceives that when this salt is dried at 200° (centigrade) it not only loses its water of crystallization, but also a portion of water derived from the elements of the acid; but that, notwithstanding this partial decomposition, it reverts to the state of perfect citrate of soda, when redissolved in water.

Citrate of Lithia is very difficultly soluble, and does not crystallize.

Citrate of Lime has been adverted to in the preparation of citric acid. It is nearly tasteless, and scarcely soluble in water, but readily soluble in solution of citric acid: when moistened, it soon grows mouldy if exposed to air. Neutral citrate of lime, dried at 212°, consists of $(cit' + C + q)$, or

				Berzelius.	Gay Lussac and Thenard.
Lime	1	28	29.5	29.70	31.17
Citric acid	1	58	61.0	60.93	68.83
Water	1	9	9.5	9.37	
	1	95	100.0	100.00	100.00

This salt is sometimes prepared in, and exported from countries where lemons and limes are abundant, as a source of citric acid.

Citrate of Baryta, when neutral, is very difficultly soluble. The *bicitrate* forms acicular crystals, soluble in water and efflorescent. The neutral citrate is represented by $(cit' + B + 2\,q.)$

Citrate of Strontia. Citric acid renders strontia-water turbid. Citrate of potassa does not precipitate nitrate of strontia, till heated.

Citrate of Magnesia is difficultly soluble, and does not crystallize.

Citrate of Manganese is formed by digesting moist protoxide of manganese in citric acid; it produces white arborescent crystals. Carbonic acid is evolved from a mixture of citric acid and peroxide of manganese.

Citrate of Iron. According to Dr. Henry (*Elements of Chemistry*, 9th edition, ii., 200), citric acid dissolves iron-filings with effervescence, and forms a nearly colourless solution, which deposits citrate of iron in the state of a white powder. It has a sweetish astringent taste; dissolves in water, but not in alcohol; and, when exposed in a moist state to the air, becomes first yellow, and then olive, being converted into a *percitrate* which is uncrystallizable and deliquescent. There is also a *bicitrate* of the protoxide, which is deposited in a white crystalline form during the solution of iron in excess of citric acid; it has a sour astringent taste, and is more permanent than the neutral protocitrate.

Citrate of Zinc. Zinc dissolves in citric acid with effervescence: citric acid readily dissolves the oxide of zinc, and the solution deposits small crystals scarcely soluble in water, and of an astringent taste.

Citrate of Tin. Neutral citrate of potassa forms no precipitate either in protomuriate or permuriate of tin.

Citrate of Copper. Citric acid forms a pale-blue precipitate in solution of sulphate and nitrate of copper. When solution of acetate of copper and citric acid are boiled together, a granular green precipitate gradually falls, composed of (3 *cit'* + 4 Cu + 4 *q*.) When dried at 212° it becomes blue, and loses half its water.

Citrate of Lead is thrown down in the state of a nearly insoluble powder, when citric acid is added to nitrate of lead. According to Berzelius, a *neutral* citrate of lead is most certainly obtained by adding an alcoholic solution of citric acid to a solution of acetate of lead, and washing the precipitate with alcohol, for water abstracts part of its acid. It consists of (*cit'* + Pl.) On digesting this neutral salt with subacetate of lead, he obtained a bibasic salt, or *dicitrate of lead* (*cit'* + 2 Pl.) By the action of ammonia on the neutral citrate he formed a subsalt, represented by (3 *cit'* + 4 Pl): and lastly, by dissolving the neutral citrate of lead in hot and very weak nitric acid, the saturated solution deposited crystals on cooling, composed of (3 *cit'* + 2 Pl + 2 *q*.)

Citrate of Antimony?

Citrate of Bismuth is an insoluble white compound.

Citrate of Cobalt appears to be a soluble salt.

Citrate of Uranium, formed by digesting oxide of uranium in citric acid, is a soluble and difficultly-crystallizable salt.

Citrate of Nickel is not thrown down by adding either citric acid or citrate of potassa to the solutions of nickel.

Citrate of Mercury. Both the *protocitrate* and *percitrate* of mercury are insoluble, and thrown down when citric acid or a soluble citrate is added to the neutral solutions of mercury.

Citrate of Silver is an insoluble white powder, which blackens when exposed to light. It detonates slightly when heated. It is the most uniform of the citrates, being always (*cit'* + Ag.)

Pyrocitric Acid. When citric acid is distilled in a retort *per se*, an acid liquid is obtained, which, when saturated by lime, affords a precipitate, which may be decomposed by oxalic acid, and thus furnishes a peculiar product called, by Lassaigne, *pyrocitric acid.* (*Ann de Chim. et Phys.*, xxi., 100.) It forms salts, perfectly distinct from the citrates; its equivalent number is 56. It consists of (5 *car* + 2 *h* + 3 *o*), or,

				Dumas
Carbon	5	30	53.5	54.07
Hydrogen	2	2	3.7	3.53
Oxygen	3	24	42.8	42.40
Pyrocitric acid	1	56	100.0	100.00

Malic Acid. The existence of a peculiar acid in the juice of *apples* was shown by Scheele, in 1785. He obtained it by adding solution of acetate of lead to the expressed juice of unripe apples, by which a *malate of lead* was formed, and afterwards decomposed by sulphuric acid. Vauquelin obtained it by a similar process, from the juice of the *houseleek.* The same acid exists, according to Braconnot and Houton Labillardière, in the berries of the *mountain-ash* (*Ann. de Chim. et Phys.*, viii., 214), from which it was first obtained by Mr. Donovan in 1815, and called by him *sorbic acid;* the apparent differences between the malic and sorbic acids are referable to the impurities of the former. Mr. Donovan has given the following process for its preparation. (*Phil.*

Trans., 1815.) Express the juice of the ripe berries, and add solution of acetate of lead, filter, and wash the precipitate with cold water; then pour boiling water upon the filter, and allow it to pass through the precipitate into glass jars: after some hours crystals are deposited, which are to be boiled with 2.3 times their weight of sulphuric acid; specific gravity 1.090. The clear liquor is to be poured off, and, while still hot, a stream of sulphuretted hydrogen is to be passed through it, to precipitate the remaining lead; the liquid is then filtered, and when boiled so as to expel the sulphuretted hydrogen, is a solution of the pure vegetable acid.

M. Braconnot procures this acid by saturating the juice of the scarcely-ripe berries with chalk; during evaporation malate of lime falls, which he decomposes by carbonate of soda; the malate of soda is decomposed by acetate of lead, and treated by sulphuretted hydrogen as before described. (*Ann. de Chim. et Phys.*, vi.)

According to Liebig (*Ann. de Chim. et Phys.*, xliii., 259, and lii., 434), pure malic acid is obtained by boiling the juice with animal charcoal, filtering, adding a little potassa, evaporating, and adding alcohol to precipitate bitartrate of potassa: then distil off the alcohol, and reduce the residue to the consistency of syrup, and again add alcohol, which throws down mucilage. The residue of the second distillation, diluted and mixed with acetate of lead, yields *malate of lead*, which is washed and decomposed by sulphuretted hydrogen: to complete the purification of the acid, its solution is concentrated, diluted by alcohol, and half saturated by ammonia: the *bimalate of ammonia* is crystallized, and used as a source of *malate of lead*, to be decomposed as before.

Malic acid is usually obtained in the state of a colourless liquid, very sour, and scarcely susceptible of regular crystallization, though when very carefully evaporated it concretes into mammillary masses, showing traces of acicular crystals. It is deliquescent, and very soluble in alcohol and water. Nitric acid converts it into oxalic acid. Malic and citric acids, when *anhydrous*, are, according to Liebig, isomeric; malic acid is therefore represented by the equivalent 58, or ($4\,car + 2\,h + 4\,o$.)

MALATES. The neutral salts of the malic acid are composed of 1 atom of acid + 1 of base, and are not subject to those capricious modifications which characterize the citrates. The neutral malates are mostly soluble in water: those of ammonia, potassa, and soda, are very soluble and deliquescent: the *bimalates* of those bases are less soluble, and are crystallizable: the neutral and bimalate of baryta are very soluble, and leave, on evaporation, gummy masses: the basic malate of baryta ($mal' + 2\,B$) is insoluble. The neutral malate of strontia is soluble; the bimalate, difficultly soluble. The same is the case with the corresponding salts of manganese. With peroxide of iron the neutral malate is uncrystallizable, soluble in water and alcohol, and deliquescent: the permalate of mercury is uncrystallizable; water resolves it into a super and a subsalt. The best mode of distinguishing the malates is to convert them into *malate of lead*, which may be easily identified. (Dumas.)

MALATE OF LIME. The neutral malate ($mal' + C$) dissolves in 150 parts of water at 60°, and in 65 parts at 212°: the hot saturated solution deposits small crystals on cooling: its taste resembles that of nitre. According to Grotthus, it dissolves readily in solutions of other salts, such as those of nitrate of potassa, chloride of sodium and of calcium, and muriate of ammonia. The *bimalate of lime* ($2\,mal' + C$) dissolves in 50 parts of water at 60°, and yields flattened six-sided prisms; insoluble in alcohol: it exists in several plants, but when obtained from their juices it is disguised by mucilage.

Malate of Magnesia ($mal' + M$), forms permanent crystals, soluble in 28 parts of water.

Malate of Lead ($mal' + Pl$), is scarcely soluble in cold water: its hot saturated solution deposits white and brilliant lamellar crystals as it cools. When first thrown down as a precipitate, it appears pulverulent, but assumes spontaneously a crystalline aspect, especially when heated. It is fusible at 212°, and then becomes less easily soluble in water: to saturate boiling water with it, it must be added in fine powder, and in successive portions. It forms uncrystallizable double salts with malate of ammonia, and malate of zinc.

Malate of Silver falls on mixing nitrate of silver with bimalate of ammonia; it is brilliant white, but becomes yellow when dried: it dissolves in boiling water, but by continued boiling it is reduced, and metallic silver separates.

Pyromalic Acid. According to Pelouze, malic acid enters into fusion at about 180°: at about 380° (176° Cent.) it is resolved into water, and two pyro-acids, which he terms *malæic* and *paramalæic acids*.

Malæic Acid is formed when malic acid is distilled at about 400°. A liquid passes over which crystallizes, and consists entirely of *malæic acid;* its taste is acid and nauseous: it is soluble in water and alcohol. The solution of this acid does not precipitate lime water: in a solution of acetate of lead it forms white flocculi, which gradually become semitransparent. The anhydrous malæic acid consists of ($4\,car + h + 3\,o$) its equivalent being 49.

Malæates. These salts have not been much examined; they closely resemble the *succinates* in many of their properties.

Paramalæic Acid is produced by the continuous action of a moderate heat upon the malæic acid; or by boiling it in a long tube, so that the evolved water constantly falls back upon the acid. This acid crystallizes in large striated prisms, soluble in 200 parts of water, and of an acid flavour. The atomic composition of this acid is identical with the malæic.

Paramalæates. The *paramalæates* of ammonia, potassa, and soda, are very soluble and crystallizable: those of lime, baryta, and strontia, are also so far soluble that the acid affords no precipitate in their respective aqueous solutions. The paramalæate of peroxide of iron is insoluble and brown; that of copper, insoluble and green; and of lead, white, and not crystalline, except when deposited from its solution in boiling water. The paramalæate of silver is so insoluble that 1 part of the acid in 200,000 of water renders nitrate of silver turbid.

Formic Acid. The peculiarities of an acid obtained by the distillation of *ants*, was first noticed by Fischer and Margraaf; but it was afterwards regarded as identical with acetic acid, upon the authority of Fourcroy and Vauquelin (*Ann. de Chim.*, lxiv., 48). Gehlen, however, (*Thomson's*

Annals, v., 24,) and more lately Berzelius, have shown that it is a distinct compound; and Döbereiner has published some curious facts respecting its artificial production. (*Ann. de Chim. et Phys.*, xx., 329, and lii., 105.) He has shown that it is the result of the peroxidizement of several vegetable compounds, and that nascent oxygen converts citric and tartaric acids, and many other organic compounds, into formic acid: numerous other instances of the formation of this acid might be adduced.

Formic acid may be obtained from a mixture of tartaric acid, black oxide of manganese, and water; or more abundantly from a mixture of 2 parts of crystallized tartaric acid, 5 of peroxide of manganese, 5 of sulphuric acid, and 5 of water. Soon after mixture, these ingredients, which should be in a sufficiently capacious retort, effervesce violently, and give off abundance of carbonic acid; if afterwards distilled, the formic acid passes over, and may be concentrated in vacuo: it possesses several peculiarities, which amply distinguish it from acetic acid, among which the most remarkable is the action of sulphuric acid, which converts it into water and carbonic oxide; and if sulphuric acid be poured upon *formiate of potassa*, which is a deliquescent and difficultly-crystallizable salt, of a saline bitter taste, an effervescence ensues, attended by the escape of *carbonic oxide* only.

Pure formic acid is best obtained by saturating the acid produced as above, by carbonate of soda, evaporating to dryness, and distilling 7 parts of the dry salt with 10 of sulphuric acid, and 4 of water. It has a pungent odour, and its combined water is only separable by uniting it to bases. It is a sour, colourless liquid, which boils at a little above 212°, without decomposition: its specific gravity is 1.1168 (Gehlen). It reduces the nitrates of silver and mercury, by simple ebullition.

The ultimate composition of formic acid in its *anhydrous* state is, $(2\,car+h+3\,o)$ and its equivalent is 37; or

				Berzelius.	Göbel.
Carbon	2	12	32.43	32.970	32.53
Hydrogen	1	1	2.70	2.807	3.06
Oxygen	3	24	64.87	64.223	64.41
Anhydrous formic acid	1	37	100.00	100.000	100.00

These elements are equivalent to 2 atoms of carbonic oxide and 1 atom of water, into which formic acid is actually resolved by the action of sulphuric acid.

FORMIATES. These salts are all soluble: they are resolved by heat into products which have not been particularly examined: they reduce the salts of silver and mercury by the aid of heat, and evolve carbonic oxide when acted on by sulphuric acid.

FORMIATE OF AMMONIA. $(for'+\mathrm{A}.)$ The ultimate components of the acid and base of this salt are $(2\,car+h+3\,o)+(n+3\,h)$; these elements are equivalent to *hydrocyanic acid* and *water*, or to $(2\,car+n+h)+3(h+o.)$ Döbereiner has shown, that simple distillation at a high temperature resolves formiate of ammonia into hydrocyanic acid and water, and Pelouze and Geiger have shown (*Ann. de Chim. et Phys.*, xlviii., 585, and xlix., 286), that under the influence of bases or acids, and water, hydrocyanic acid is convertible into formic acid and ammonia.

The *formiates* of potassa, soda, lime, baryta, strontia, and magnesia, are crystallizable and soluble: that of alumina is uncrystallizable, and when its solution is boiled the base falls. The formiate of lead yields brilliant prismatic crystals, soluble in 36 parts of water at 55°, and consisting of 37 acid + 112 oxide. Formiate of copper crystallizes in greenish-blue hexagonal tables or prisms, efflorescent, soluble in 8.5 of water, and including 4 atoms of water + 1 anhydrous formiate.

SUBERIC ACID. This acid was originally obtained by the action of nitric acid upon *cork*, by Brugnatelli (Crell's *Annals*, 1787, i., 154). It was afterwards examined by Bouillon Lagrange (*Ann. de Chim.*, xxiii., 42), and more lately by Chevreul, Brandes, and Bussy.

Suberic acid is obtained as follows (Chevreul, *Ann. de Chim. et Phys.*, lxii., 323). Rasped cork is digested in 6 times its weight of nitric acid; it is slowly dissolved, and a fatty matter separates upon the surface: this is separated, and the solution evaporated at a gentle heat, and constantly stirred till it acquires a thick consistence; it is then diluted with 6 or 8 parts of water, and heated so as to separate an additional quantity of fat; the solution is then filtered and evaporated, and during cooling, oxalic acid and suberic acid are deposited; the latter in the form of a white powder: it may be purified by dissolving it in ammonia, precipitating the filtered solution by an acid, and washing the precipitate with cold water: it is sometimes purified by sublimation.

Suberic acid falls from its solution in hot water, in the form of a white powder, slightly acid, fusible at 300°, and subliming in acicular crystals: it dissolves in between 5 and 6 parts of anhydrous alcohol. The composition and equivalent of this acid as given upon different authorities are various: according to Bussy, (*Jour. de Pharm.*, viii., 110, and xix., 425,) anhydrous suberic acid is a compound of $({}_{8}\,car + {}_{6}\,h + {}_{3}\,o)$ and its equivalent is 78.

				Bussy.	Bouillon Lagrange.
Carbon	8	48	61.5	61.99	58.33
Hydrogen	6	6	7.7	7.59	7.67
Oxygen	3	24	30.8	30.42	34.00
Anhydrous suberic acid	1	78	100.0	100.00	100.00

SUBERATES. These salts have been examined by Brandes (Schweigger's *Jahrbuch*, II., III., and VI.) The *suberates* of potassa and of soda are soluble, deliquescent, and fusible without decomposition: those of ammonia, lime, baryta, strontia, magnesia, manganese, and alumina, are more or less soluble: the suberate of protoxide of iron is precipitated white; that of peroxide, brown: the suberates of zinc, tin, mercury, and silver, are also in the form of white precipitates: the suberates of cobalt, copper, and uranium, are red, blue-green, and yellow, and insoluble. The suberate of lead and of silver are anhydrous, and consist of 78 acid + 112 oxide = $(sub' + \mathrm{Pl})$, and 78 acid + 116 oxide = $(sub' + \mathrm{Ag})$.

BOLETIC ACID. This acid was obtained by Braconnot from the *Boletus pseudo-igniarius*, (*Ann. de Chim.*, lxxx.), by cautiously evaporating its expressed juice to the thickness of syrup, digesting it in alcohol, dissolving the residue in water, and adding nitrate of lead to the aqueous solution; the precipitate, washed and diffused through water, was decomposed by sulphuretted hydrogen; the liquor was then filtered and evaporated till it formed crystals, which were purified by solution in alcohol and evaporation. These crystals are *boletic acid;* they are prismatic, and require 180 parts of water at 68°, and 45 of alcohol for their solution, which reddens blues, and precipitates nitrate of lead, and the salts containing the peroxide, but not those of the protoxide of iron. This acid sublimes, with little alteration, when heated. Braconnot has examined the *boletates of ammonia*, *potassa*, *lime*, and *baryta*, but his researches have not as yet been confirmed by any other chemist.

Fungic Acid was procured also by Braconnot from the *Boletus juglandis*, and some other *fungi;* it is deliquescent and uncrystallizable. (*Ann. de Chim.*, lxxxvii.)

Lichenic Acid apparently much resembles the boletic: it was obtained by Pfaff, by digesting lichen in a weak solution of carbonate of potassa, saturating this infusion with acetic acid, adding acetate of lead, filtering off the precipitate, and leaving the filtered liquor to itself: it slowly deposits crystals of *lichenate of lead*, from which *lichenic acid* was obtained by the action of sulphuretted hydrogen. This acid is soluble in water and alcohol, and forms acicular crystals, which are volatile when heated, without either fusion or decomposition. The *lichenates* of ammonia, potassa, and soda, are soluble and crystallizable; that of lime difficultly soluble; and those of baryta, strontia, zinc, manganese, and peroxide of iron, insoluble, or nearly so.

Equisetic Acid. A peculiar acid combined with magnesia, was discovered by Braconnot in the *Equisetum fluviatile.* (*Ann. de Chim. et Phys.*, xxxix., 10.)

Moroxylic Acid, discovered by Klaproth in the bark of the *Morus alba*, or *white mulberry.* (Nicholson's *Journal*, vii.) An exudation was observed upon this bark, which proved to be a compound of a peculiar acid and lime, or a *moroxylate of lime;* its solution was decomposed by acetate of lead, and the *moroxylate of lead* thus obtained, decomposed by dilute sulphuric acid, furnished a solution of moroxylic acid, which gave acicular crystals on evaporation. This acid has the taste of succinic acid; it is soluble in water and alcohol, and does not, like some of its salts, form precipitates in metallic solutions. The quantity of this acid examined by Klaproth was so small, as to leave some doubt respecting its distinct nature.

Verdic Acid. This acid was extracted by Runge, from several of the *Umbelliferæ* and *Plantagineæ*, &c., but chiefly from the root of the *Scabiosa succisa*, which, when dried, powdered, and digested in alcohol, yields a tincture from which ether throws down white flakes; these are dissolved in water, acetate of lead is added, and the precipitate decomposed by sulphuretted hydrogen. On evaporation a *yellow* acid product is obtained: in this state Berzelius proposes to call it *verdous acid.* When saturated by an alkali, and exposed to air, it absorbs oxygen and becomes *green.* (Dumas, v., 416.) The further examination of these compounds may, perhaps, throw some light upon the nature of the green colouring-matter of leaves and plants.

[The organic acids not hitherto mentioned, are noticed under other heads.]

§ XVIII. VEGETABLE ALKALOIDS, AND SUBSTANCES ASSOCIATED WITH, OR ALLIED TO THEM.

THE discovery of these substances is one of the most curious and important of modern chemistry. The first of them was detected in *opium*, in 1816, by Sertuerner of Einbeck, near Hanover. Several others were afterwards pointed out by Pelletier and Caventou, and among them *cinchonia* and *quinia*, (in different species of *cinchona*,) which have proved of so much use in medicine; more lately, several others have been added to the list. These *salifiable bases* appear all to contain *nitrogen* as one of their ultimate elements; they have a bitter taste, are, for the most part, very sparingly soluble in water, more soluble in alcohol, and readily soluble in most of the dilute acids: with infusion of galls, and with excess of iodic acid, they furnish difficultly-soluble precipitates; their compounds with the acids are decomposed and precipitated by the alkalis. They are mostly crystallizable; and are represented by very high equivalent numbers. They restore the blue colour to reddened litmus. They are found in plants united to certain *acids*, and usually forming neutral or acid salts, which, as well as their artificial combinations, are decomposed in the voltaic circle, and the base is evolved at the negative pole.

In consequence of the analogy that pervades these principles, one general method of separating them is applicable to all, though each may require peculiar modifications of it. The substance which contains them is boiled in water acidulated by muriatic acid, the decoction is filtered and neutralized by ammonia, lime, or magnesia; the alkaloid is precipitated, and is then to be separated and purified.

I. MORPHIA: AND THE COMPONENT PARTS OF OPIUM. The chemical examination of *opium* has been remarkably productive in interesting results. It has led to the discovery of several alkaloids, and of a peculiar acid, with which they are combined; the substances which we shall have to describe under this head being the following: viz., morphia, narcotina, codeia, narceia, meconia, thebaia, and meconic acid.

Opium is the inspissated milky juice which flows from incisions made in the unripe seed-capsule of the poppy; it is only effectively obtained in warm climates, and is imported into this country chiefly from Turkey and India: it contains the above-mentioned substances, upon which its extraordinary medicinal powers depend, together with several others of little importance, such as, gum, resin, extractive, ligneous matter, oil and caoutchouc.

1. MORPHIA. The first step in the process for extracting morphia, and the other alkaloids, consists in cutting the opium into small pieces, and digesting it in distilled water at the temperature of about 100°, till its soluble parts are completely extracted: it affords a clear brown infusion, smelling strongly of opium, and *acid* to tests. There are several modes of separating the morphia from it, but among them the two following are generally employed:—

a. The infusion of opium is concentrated by evaporation, and ammonia is dropped into it till that alkali is in slight excess; the precipitate which falls, and which is *chiefly* morphia and narcotina, is digested in *proof spirit*, at a temperature of about 130°, which dissolves the greater part of the colouring-matter and narcotina: the morphia which remains is dissolved in boiling absolute alcohol, and separates in crystals on cooling and evaporation.

b. But the best process for the extraction of these substances is that proposed by Drs. Gregory and Robertson. The solution of opium is, if necessary, somewhat concentrated by evaporation, and a solution of pure chloride of calcium is added in sufficient quantity to precipitate all the sulphuric and meconic acids by which the alkaloids are held in solution: it is then filtered, evaporated to the consistency of syrup, and set aside to crystallize; the crystals are strongly pressed to squeeze out the mother-liquor, which contains resin, extract, narcotine, and other matters; the pressed crystals are then purified by treatment with animal charcoal and repeated crystallization, till they are obtained colourless: they consist of muriate of morphia and muriate of codeia: they are then dissolved in hot water, and ammonia is added, by which *morphia* is thrown down, and which being separated by filtration, and dissolved in boiling alcohol, is obtained in pure crystals. The liquor from which the morphia has been precipitated, contains codeia in combination with muriate of ammonia and some morphia: it is to be evaporated till it crystallizes, and the crystallized mass dissolved in a small quantity of water and decomposed by excess of caustic potassa; codeia is thrown down, and when dissolved in ether, may be procured crystallized by its evaporation.

The preceding, with some slight modifications, and technical manipulation is the best of the numerous processes which have been suggested for the preparation of morphia; of these, the reader will find an abstract in Dumas, (*Chim. app. aux Arts.*, v., 770.)

Morphia, when obtained from its alcoholic solution, is in small brilliant and colourless crystals: they are generally six-sided prisms, with diëdral terminations, but their primary form is a right rhombic prism. According to Liebig, these crystals are a *hydrate of morphia.* (*Ann. de Chim. et Phys.*, xlvii. 198.) When gently heated, they become opaque and lose water: at a higher temperature morphia fuses into a yellow liquid, which becomes white and crystalline on concreting. In the air it burns with a bright resinous flame. Morphia, though apparently insoluble in cold water, has a very bitter taste: boiling water dissolves not more than a hundredth of its weight, but the solution is alkaline to delicate tests. It dissolves in 40 parts of cold, and 30 of boiling anhydrous alcohol. It is almost insoluble in ether; hence the method of separating it from narcotine, which is readily soluble in that menstruum. Morphia, according to Wittstock, as quoted by Berzelius, is soluble in potassa and soda, hence the necessity of avoiding the use of those alkalis in its precipitation. Ammonia dissolves it very sparingly, so that even that alkali ought not to be used in excess.

The quantity of morphia obtained from opium is variable; the produce is greatest from Turkey opium, and least from the East Indian and Egyptian. The average is about 1 oz. from the lb.

Much has been said respecting the methods of detecting morphia by tests: those which are commonly resorted to are nitric acid, which, when dropped upon crystallized morphia, forms a bright-red solution;

and neutral perchloride of iron, which produces a very characteristic blue colour (or blue-green); when added to morphia, or to its salts, provided the solutions are not very dilute. Iodic acid is, according to Serullas, the best test of the presence of morphia; it produces a reddish-brown colour, and the odour of iodine is immediately perceptible. The minutest quantity of morphia has the property of decomposing iodic acid, but in cases where very small quantities are present, a solution of starch should be employed to detect the free iodine.

Morphia, in its anhydrous state is, according to Liebig, a compound of ($_{34}car + _{18}h + _{6}o + n$), its equivalent being 284: or, in detail, as follows,

			Liebig.	Brande.	Bussy.
Carbon	34	204	71.80	72.0	69.0
Hydrogen . . .	18	18	6.34	5.5	6.5
Oxygen	6	48	16.90	17.0	20.0
Nitrogen	1	14	4.96	5.5	4.5
Anhydrous Morphia	1	284	100.00	100.0	100.0

Crystallized Morphia includes, according to Liebig, 2 atoms of water, and is consequently represented by the equivalent 302, or (284 + 18.)

SALTS OF MORPHIA. These salts are generally obtained by dissolving pure morphia in the dilute acids: they are colourless, and nearly all crystallizable, bitter, and give a precipitate of morphia with the alkaline carbonates, and with ammonia. Tannin, and infusion of galls, give precipitates with them, which are redissolved by acetic acid.

SULPHATE OF MORPHIA (Mor + S') crystallizes in groups of acicular crystals, soluble in about twice their weight of water. This salt consists of

				Liebig.
Morphia	1	284	75.2	75.38
Sulphuric acid	1	40	10.6	10.49
Water	6	54	14.2	14.13
Crystallized sulphate of morphia	1	378	100.0	100.00

Dried at 250° this salt loses 4 atoms of water, but retains the 2 remaining atoms, (the quantity requisite to constitute crystallized morphia,) till heated up to its decomposing-point, so that that portion of water seems essential to the constitution of the sulphate.

BISULPHATE OF MORPHIA (Mor + 2 S) is obtained by dissolving the sulphate in excess of acid, and digesting in ether, which removes the excess of acid, but does not dissolve the bisulphate.

MURIATE OF MORPHIA. (Mor + mur'.) This salt is formed in Gregory and Robertson's process above detailed: it may be produced directly by the action of muriatic gas upon anhydrous morphia: it forms acicular and plumose crystals, soluble in about 20 parts of water, and when the hot solution cools, it concretes into a crystalline mass: this is the case when the salt is prepared by dissolving morphia in hot liquid muriatic acid. Muriate of morphia is an *anhydrous* salt, composed of

				Liebig.
Morphia	1	284	88.47	88.7
Muriatic acid	1	37	11.53	11.3
Muriate of morphia . . .	1	321	100.00	100.0

Nitrate of Morphia (Mor $+n'$) is formed by dissolving morphia in very dilute nitric acid. It yields stellated groups of crystals, soluble in 1.5 of water.

Phosphate of Morphia (Mor $+p'$) crystallizes in cubes.

Acetate of Morphia (Mor $+ac'$) is frequently formed for medical use by dissolving a given weight of morphia in a sufficient quantity of distilled vinegar. It crystallizes difficultly in acicular bundles. During evaporation it easily parts with a portion of its acid, and is apt to be of uncertain composition, hence it is less appropriate for medical use than the muriate or sulphate.

2.—Codeia. This alkaloid was discovered by Robiquet, in 1832, in the muriate of morphia prepared by Gregory and Robertson's process. (*Ann. de Chim. et Phys.*, li. 259.) On dissolving the mixed muriates in water, and precipitating the morphia by ammonia, the codeia remains, as already remarked, in solution, and crystallizes by subsequent evaporation: it may be separated, as above stated, by ether. According to Pelletier, 100 pounds of opium yield 6 ounces of codeia; according to Christison, the proportion of codeia varies in the varieties of opium: amounting in Turkey opium to one-thirtieth, and in East Indian opium to one-twelfth of the muriate of morphia obtained from those respective varieties.

Codeia crytallizes in acicular, or flat prisms, colourless and transparent. It fuses without decomposition when heated in a tube to about 300°, and the mass crystallizes on cooling. In the air, it burns away with a smoky flame. Water, at 60°, dissolves 1.26 *per cent.*: at 110°, 3.7, and at 212°, 5.9 *per cent.* When it is present in larger proportions than the water can dissolve, the excess fuses, and remains at the bottom of the solution. Its solution is sensibly alkaline to tests. Codeia is soluble in the dilute acids, and forms distinct and easily-crystallizable salts. Its medicinal action has not been accurately determined. It is distinguished from morphia by its greater solubility in water, by its insolubility in fixed alkalis, by its not being reddened by nitric acid, nor blued by perchloride of iron.

Codeia is represented by $({}_{31}car + {}_{20}h + {}_{5}o + n)$ its equivalent being 260; or

				Robiquet.
Carbon	31	186	71.6	72.0
Hydrogen	20	20	7.7	7.5
Oxygen	5	40	15.4	15.1
Nitrogen	1	14	5.3	5.4
Anhydrous codeia	1	260	100.0	100.0

Crystallized codeia includes 2 atoms of water, its symbol therefore is, (Cod $+ {}_{2}q$) and its equivalent 278. (260 + 18.) The only salt of codeia which has been analyzed, is the *muriate*, it is anhydrous, and consists of 260 codeia + 37 muriatic acid, its equivalent being 297, and its abbreviated symbol (Cod $+mur'$.)

3. Narceia. This alkaloid, discovered by Pelletier in 1832, was obtained as follows: (*Ann. de Chim. et Phys.*, l. 262.) An infusion of Turkey opium was filtered and very carefully evaporated till it left a solid extract, which, redissolved in distilled water, left a large portion of crystallized narcotina; this being separated, the liquid was heated to 212°,

and a slight excess of ammonia added to throw down morphia, after which the ebullition was continued for 10 minutes to drive off ammonia: on cooling, the morphia crystallized, not pure, but mixed with narcotina and meconia. After having thus separated the greater part of the morphia by ammonia, the residuary liquor was reduced to half its original bulk by evaporation, and on cooling, morphia was again deposited, which being removed, baryta-water was added to the liquor, by which meconate of baryta was thrown down and separated by filtration. Subcarbonate of ammonia was then added to the filtered liquor to separate the remaining baryta, and heat applied, to drive off the excess of the subcarbonate of ammonia. The liquor was then filtered, evaporated to the consistence of thick syrup, and left for several days in a cool place, when it formed a pulpy mass including crystals: this was suffered to drain, dried by strong pressure in linen, and digested in boiling alcohol: the alcoholic solution, reduced to a small bulk by distillation, furnished on cooling a crystalline substance: this, purified by repeated solutions and crystallization, is *Narceia*.

Pure *narceia* forms white silky crystals, or acicular prisms, inodorous, bitterish and slightly pungent, soluble in 375 parts of cold and in 230 of boiling water; soluble in alcohol but not in ether; fusible at about 198°, and concreting into a white translucent and somewhat crystalline mass; it becomes yellow at 220°, and at higher temperatures is decomposed: it is more fusible than morphia or narcotina. It is decomposed by the stronger acids, but when diluted they dissolve and combine with it, producing at first a blue colour, which passes into purple or red, and then disappears. Narceia appears to consist of

				Pelletier.
Carbon	32	192	54.4	54.73
Hydrogen	20	20	5.7	6.52
Oxygen	16	128	36.0	34.42
Nitrogen	1	14	3.9	4.33
Anhydrous narceia	1	354	100.0	100 00

4. Meconia. This substance was discovered by Dublanc and Couerbe (*Ann. de Chim. et Phys.*, L.) They obtained it by digesting opium in cold water, filtering the infusion, concentrating it by evaporation, and adding ammonia as long as it occasions a precipitate: after some days the supernatant liquid is poured off, gently evaporated to the consistence of syrup, and left in a cool place for 15 or 20 days, when it deposits granular crystals, which are collected, drained, pressed, and dried by a gentle heat: they contain meconia, narceia, and other substances: they are boiled in alcohol, and the solution is evaporated to about one-third its bulk, when on cooling it deposits crystals, which are collected, dissolved in boiling water, and filtered with animal charcoal; white crystals are obtained of meconia and narceia; ether dissolves the former, and leaves the latter; on evaporating the ethereal solution the meconia remains. (This is only an outline of the essential parts of the process: the details of manipulation are omitted, but they will suggest themselves to the practical operator. The quantity of meconia in opium is so small, that from 15 to 20 lbs. must be operated upon satisfactorily to extract it.)

Meconia is white, inodorous, slightly acrid on the tongue, soluble in water, alcohol, and ether, and crystallizable: it fuses at 195°, and at about

350°, it distils over unaltered, and concretes into a white mass looking like fat. It forms a colourless solution in sulphuric acid diluted with half its weight of water, but on applying heat to this solution it becomes green and is decomposed. Nitric acid dissolves it, and converts it into a peculiar crystallizable product. It is decomposed by chlorine.

The nature of this substance has been hitherto very imperfectly ascertained: according to Couerbe it contains no nitrogen, but consists of $({}_{9}car + {}_{4}h + {}_{4}o) = 82$: or *per cent.* 60.23 carbon, 4.74 hydrogen, 35.03 oxygen.

5. Thebaia. This crystalline substance, discovered also by Couerbe, requires, like the former, further examination; it exists in opium in small proportion only, and can only be obtained, therefore, by those who have an opportunity of operating upon large quantities. Thebaia is represented as eminently alkaline, and as forming distinct salts by solution in the dilute acids. It is converted into a resinous product by the stronger acids, and is soluble in alcohol and ether.

6. Narcotina. This well-defined and distinct principle was discovered in 1804 by Derosne (*Ann. de Chim.*, xlv. 257.) Its peculiarities were first pointed out by Robiquet in 1817 (*Ann. de Chim. et Phys.*, v., and li., 275.) Its alkaline characters are not very distinct, but the compounds which it forms with the acids, and its ultimate composition, place it among the alkaloids. It is contained in some kinds of opium, especially in that recently imported under the name of *Egyptian opium*, in a proportion nearly, if not quite, equal to that of the morphia. The effects of this substance upon the animal economy have not been very satisfactorily ascertained, but there can be little doubt that they are perfectly distinct from those of morphia, and that opium deprived of narcotina, is more directly sedative, and less stimulating; hence the important uses of the salts of morphia in preference to opium, and the advantage of using opium, in many instances at least, from which the narcotina has been abstracted.

Narcotina may be obtained from powdered opium by digesting it in warm ether, which takes up little else than narcotina, and yields it in crystals. When caustic potassa is added to an aqueous solution of opium, so as just to saturate the free acid, the matter which falls consists chiefly of resin and narcotina. When all the soluble parts of opium have been extracted by water, the residue, digested in dilute muriatic acid, also yields narcotina*. Other means of obtaining narcotina and of separating it from morphia, will be evident, from the account of that alkaloid. Dr. Robertson's method consists in boiling the impure morphia in water, and adding muriate of ammonia, as long as ammonia is evolved in consequence of the decomposition of that salt by the morphia, at a boiling heat; the muriate of morphia so formed is dissolved, and the narcotina remains.

Narcotina is deposited from its alcoholic or ethereal solution in well-defined crystals, insoluble in cold, and very sparingly soluble in hot water; soluble in the fat oils; not bitter; and yielding no blue colour with perchloride of iron: it is readily soluble in dilute acids, and yields salts which have been but imperfectly examined: they are very bitter, and difficultly obtained in the crystalline state, for when evaporated they are mostly decomposed into acid and narcotina, and crystals of the latter only separate. This is especially the case with the acetate of narcotina, and furnishes a means of separating it from morphia, for the latter substance is retained in permanent combination and solution. Narcotina absorbs muriatic acid gas, and is extremely soluble in muriatic acid, yielding a salt which is best obtained by carefully evaporating the muriatic solution of narcotina to dryness and redissolving in alcohol, from which solution the crystallized *muriate of narcotina* may be obtained: it consists, according to Robiquet of 91.1 narcotina + 8.9 muriatic acid. According to Liebig narcotina consists of $({}_{40}car + {}_{20}h + {}_{12}o + n) =$ 370 or

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* For beautiful specimens of the principal products of opium, and for much useful information respecting these and the other alkaloids, I am much indebted to Mr. Morson of Southampton-row, who prepares them upon an extensive scale.

				Liebig.
Carbon	40	240	65.0	65.27
Hydrogen	20	20	5.4	5.32
Oxygen	12	96	25.9	25.63
Nitrogen	1	14	3.7	3.78
Narcotina	1	370	100.0	100.00

7. Meconic Acid. The existence of a distinct acid in opium was announced by Seguin in 1804 (*Ann. de Chim.*, xcii. 225) and shortly afterwards by Sertuerner, who gave it the above name (from μηκων, poppy) (*Ann. de Chim. et Phys.*, v., 21.) It may be most conveniently extracted from the precipitate obtained by adding chloride of calcium to infusion of opium, in the process for procuring morphia, (p. 1016.) This precipitate is washed first with water, and then with hot alcohol, and mixed with 10 times its weight of water, at 195°, and muriatic acid is gradually added, so as to dissolve the *meconate of lime* (which forms the bulk of the precipitate) and leave the sulphate of lime; the solution is filtered, and on cooling deposits crystals of *bimeconate of lime:* these are again dissolved in hot dilute muriatic acid, by which the lime is abstracted, and crystals of meconic acid obtained, which, if pure, should leave no residue when burned: they must be redissolved in the acid, and recrystallized, till they are obtained in this state, but care must be taken to keep the temperature of their solutions below 212°. To abstract the whole of the colouring-matter from this acid, it must be saturated by a weak solution of caustic potassa, and the meconate of potassa dissolved by the aid of gentle heat in a little water: when cold, the fluid part, which retains the colour, must be pressed out of the crystals, and these, decomposed as before by muriatic acid, ultimately yield the meconic acid in small white crystals, which must be dried at a temperature below 100°.

Meconic acid crystallizes in transparent and micaceous scales of an acid taste, soluble in 4 parts of hot water, and in alcohol. The crystals are permanent in the air, but when heated to 212° they lose 21.5 *per cent.* of water: they then sustain a temperature of 240° without decomposition; but if boiled in water, carbonic acid is evolved, the solution becomes brown, and *metameconic acid* is formed.

Meconic acid consists, according to Liebig, (*Ann. de Chim.*, liv., 26,) of $({}_{7}car + {}_{2}h + {}_{7}o)$, its equivalent being = 100, or

			Liebig.
Carbon	7	42	42.46
Hydrogen	2	2	1.98
Oxygen	7	56	55.56
Meconic acid	1	100	100.00

Meconates. The meconic acid forms neutral, acid, and subsalts: the bimeconates are difficult of decomposition. One of the leading characters of this acid and of its salts, is that of forming compounds with the peroxide of iron of an intensely red colour, very similar to that of the sulphocyanate of iron; so that the persalts of iron are excellent tests of its presence, and by them opium may sometimes be recognised, where the quantity is so small as to render the morphia very difficult of detection. This red colour is destroyed by heat, and by sulphurous acid and protochloride of tin; but it returns on exposure to air, or on the addition of a few drops of nitric acid.

The meconates of ammonia and of potassa become less soluble by excess of acid; the meconates of lime, baryta, strontia, and lead, are rendered more soluble by excess of acid; when neutral, they are insoluble, or nearly so, in water; but soluble in nitric acid. The meconate of lead may be decomposed by sulphuretted hydrogen. The *meconate of silver* $(\mathrm{Ag} + mec')$ is thrown down in the form of a white powder, when nitrate of silver is dropped into a solution of meconic acid: if the precipitate be redissolved by the addition of nitric acid, and the mixture heated, *cyanuret of silver* is produced: the liquid, originally transparent, becomes opaque from the formation of the cyanuret, and when this is deposited, *oxalate* of silver is found in the supernatant liquid, which may be thrown down by the cautious addition of ammonia: excess of nitric acid converts the whole into oxalate, without any formation of cyanuret. (Liebig.)

8. Metameconic Acid. When an aqueous solution of meconic acid is boiled, it is converted into metameconic acid and carbonic acid: the acid at the same time becomes discoloured; so that pure and colourless metameconic acid is best obtained by decomposing meconate of potassa or of lime, at a *boiling heat*, by muriatic acid; it is then less coloured, and may be obtained colourless by the help of animal charcoal.

Metameconic acid is less soluble than the meconic; it forms hard crystalline grains, requiring 16 parts of hot water for solution. It reddens the persalts of iron; and is converted into oxalic acid by nitric acid. The neutral metameconates of ammonia and potassa are difficultly soluble in water: excess of acid renders them more soluble.

Metameconic acid is anhydrous, and consists, according to Liebig, of $(12\,car + 4\,h + 10\,o)$, its equivalent being 156, or

				Liebig.
Carbon	12	72	46.1	46.62
Hydrogen	4	4	2.7	2.53
Oxygen	10	80	51.2	50.85
Anhydrous metameconic acid	1	156	100.0	100.00

Hence 2 atoms of meconic acid $= 2\,(7\,car + 2\,h + 7\,o)$, yield 1 atom of metameconic acid $= (12\,car + 4\,h + 10\,o)$, and 2 atoms of carbonic acid $= 2\,(car + 2\,o)$, and this represents the change which the meconic acid suffers when boiled with water.

9. Pyromeconic Acid. This acid is among the products of the destructive distillation of the meconic acid; it is a crystalline sublimate, which fuses at a temperature of about 250°. It is volatile, soluble in water and alcohol, reddens the persalts of iron, and forms many soluble salts. This acid, when anhydrous, appears to be constituted of $(10\,car + 3\,h + 5\,o) = 103$. The neutral pyromeconate of lead consists of

				Liebig.
Pyromeconic acid	1	103	47.9	48.3
Oxide of lead	1	112	52.1	51.7
Anhydrous pyromeconate of lead	1	215	100.0	100.0

Dumas observes, that the *hydrated* pyromeconic acid, consisting of 1 atom of the anhydrous acid and 1 of water, is isomeric with the anhydrous pyrocitric, and with the hydrated pyromucic acid.

II. Cinchonia. Quinia. Aricina. Cinchonic Acid. The existence of a peculiar principle in *pale Peruvian bark*, (the bark of the *Cinchona Condaminea* or *lancifolia*,) was originally suggested by the late Dr. Duncan; he considered it as the source of its medicinal powers, and proposed to call it *Cinchonine:* it was afterwards procured in a crystalline form by Dr. Gomès of Lisbon; but its peculiar alkaloid properties, and ready and certain methods of preparing it, were first made known by Pelletier and Caventou, in 1820. (*Ann. de Chim. et Phys.*, xv., 291 and 337.) They also discovered another analogous but distinct principle in *Yellow Peruvian Bark* (*Cinchona cordifolia*), which has been termed *Quinia;* and in the *Red Peruvian Bark* (*Cinchona oblongifolia*), they found the two preceding alkaloids, nearly in equal proportions. In 1829, Pelletier and Coriol discovered a third alkaloid in a species of bark from Arica, the botanical history of which is not known, but which they have termed *Aricina*[*].

1. Cinchonia. This alkaloid may be obtained from pale Peruvian bark[†], by the following process. A pound of the bruised bark (*Cinchona lancifolia* of the Pharmacopœia) is boiled in about a gallon of water, acidulated by three fluid drachms of sulphuric acid. A similar decoction is repeated with about half the quantity of liquid, and so on, till all the soluble matter is extracted. The decoctions are then mixed and strained, and powdered lime added, in a proportion somewhat greater than necessary to saturate the acid: the precipitate that ensues (a mixture chiefly of cinchonia and sulphate of lime) is collected, *carefully* dried, and boiled for some minutes in strong alcohol, which is then decanted off, while hot, and fresh portions are successively added for the repetition of the same operation, until it ceases to act upon the residue, which is now little else than sulphate of lime. The different alcoholic solutions are then put into

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[*] The French chemists designate these bases by the termination *ine*, morphine, quinine, &c. As far as possible *we* are in the habit of distinguishing *salifiable bases* by the termination *a*, hence our terms *morphia*, *quinia*, *cinchonia*, &c.

[†] The varieties of Peruvian bark have been examined by MM. Pelletier and Caventou. In the *Cinchona lancifolia*, or *pale bark*, they found the following constituent parts:—1. Cinchonia, combined with kinic (or cinchonic) acid. 2. Green fatty matter. 3. Red and yellow colouring-matter. 4. Tannin. 5. Kinate (or cinchonate) of lime. 6. Gum. 7. Starch. 8. Lignin.

a retort or still, and considerably evaporated; during which, and especially on cooling, cinchonia is deposited. When the whole is thus collected, the cinchonia must be redissolved in alcohol, and crystallized by its slow evaporation. It may be deprived of colour and slight impurities by the action of animal charcoal, and two or more crystallizations. In the preceding process muriatic acid may be used instead of sulphuric, in which case the precipitate is not encumbered with sulphate of lime.

Cinchonia is thus obtained in the form of white semitransparent crystals, requiring about 2500 parts of water, at 212°, for their solution, and are almost insoluble in cold water. They have little taste, but become intensely bitter upon the addition of almost any acid. They restore the blue colour of reddened litmus. They are sparingly soluble in cold alcohol, ether, and fixed oils; but abundantly soluble in boiling alcohol, and the solution deposits crystals on cooling, and becomes milky when dropped into water.

When cinchonia is heated in a small tube-retort, ammonia is evolved, recognised by its odour, action upon turmeric, and upon a glass rod moistened with muriatic acid: the odour of hydrocyanic acid may also be perceived; an oily matter, smelling like naphtha, distils over, and an abundant carbonaceous residue remains. The most remarkable circumstance attending this decomposition (provided the cinchonia be pure, and air carefully excluded), is the absence of aqueous vapour, even when the products were made to pass through a cooled tube. This led me to suspect the absence of oxygen in cinchonia (*Quarterly Journal*, xvi.); an opinion corroborated by its want of action upon potassium when heated with that metal in naphtha: the cinchonia, under these circumstances, readily dissolves in boiling naphtha, and again entirely separates as the solution cools, concreting into a radiated crystallized mass, in which the brilliant globules of potassium are disseminated. The experiments which I made to determine the ultimate components of cinchonia, led me to regard it as a ternary compound of 79.3 *per cent.* carbon, 7.1 hydrogen, and 13.6 nitrogen, and I represented it as a *base*, of which certain other alkaloids might possibly be *oxides:* but the subsequent, and probably more accurate researches of Pelletier and Dumas have shown that it consists of $(20\,car + 11\,h + o + n)$, its apparent equivalent being 153: or

				Dumas and Pelletier.	Brande.
Carbon	20	120	78.5	78.67	79.3
Hydrogen	11	11	7.2	7.06	7.1
Oxygen	1	8	5.2	5.16	0.0
Nitrogen	1	14	9.1	9.11	13.6
Cinchonia	1	153	100.0	100.00	100.0

The salts of cinchonia have been examined by Baup (*Ann. de Ch. et Phys.*, xxvii., 323), and by Pelletier, Caventou, and Dumas (*Ib.*, xv. and xxiv.)

SULPHATE OF CINCHONIA. There is a *subsulphate* or disulphate, and a neutral sulphate of this base. The *neutral sulphate*, obtained by dissolving cinchonia in excess of dilute sulphuric acid, and evaporating till a pellicle forms, crystallizes in rhomboidal octoëdra, which become opaque, and are efflorescent, soluble in less than their weight of water at 60°, and in alcohol; but not in ether. They consist of $(\text{Cin} + s' + 4\,q)$, or

				Baup.
Cinchonia	1	154	66.7	67.241
Sulphuric acid	1	40	17.6	17.241
Water	4	36	15.7	15.518
Crystallized sulphate of cinchonia	1	230	100.0	100.000

SUBSULPHATE, OR DISULPHATE OF CINCHONIA. This salt requires between 50 and 60 parts of water at 60° for its solution: it is obtained by digesting excess of cinchonia in the dilute acid: it forms rhomboidal prisms $= (2\ \text{Cin} + s' + 2\ q)$, or composed of

			Baup
Cinchonia	2	308	84.41
Sulphuric acid	1	40	10.91
Water	2	18	4.68
Crystallized disulphate of cinchonia	1	366	100.00

MURIATE OF CINCHONIA. $(\text{Cin} + mur'.)$ Anhydrous cinchonia absorbs muriatic acid gas, and produces a neutral muriate, composed, according to Liebig, of

				Liebig.
Cinchonia	1	154	80.4	81
Muriatic acid	1	37	19.6	19
Muriate of cinchonia	1	191	100.0	100.

SUBMURIATE, OR DIMURIATE OF CINCHONIA. $(2\ \text{Cin} + mur'.)$ When cinchonia in excess is digested in dilute muriatic acid, a soluble salt, forming acicular crystals, is obtained, composed, according to Pelletier and Caventou, of

				Pelletier and Caventou.
Cinchonia	2	308	89.1	89.5
Muriatic acid	1	37	10.9	10.5
Dimuriate of cinchonia	1	345	100.0	100.0

NITRATE OF CINCHONIA. $(\text{Cin} + n'.)$ When very dilute nitric acid is saturated by cinchonia, a portion of the *nitrate* formed separates in the form of liquid globules, looking like oil, which, in the course of a few days, become groups of acicular crystals. This property belongs also to quinia, and may serve to distinguish these from other alkaloids.

CHLORATE OF CINCHONIA, $(\text{Cin} + c')$, obtained by saturating chloric acid by cinchonia, forms clusters of white crystals. When heated, they first fuse and then explode.

IODATE OF CINCHONIA forms delicate prismatic crystals.

ARSENIATE OF CINCHONIA is a very soluble, and difficultly-crystallizable salt.

GALLATE OF CINCHONIA is a difficultly-soluble salt.

OXALATE OF CINCHONIA. The neutral oxalate is difficultly soluble in cold water: it is rendered more soluble by excess of acid; it is thrown down when oxalate of ammonia is added to a neutral solution of a salt of cinchonia, in the form of a white powder, very sparingly soluble in hot water: this salt is soluble in hot alcohol, and part separates as the solution cools.

ACETATE OF CINCHONIA. Acetic acid dissolves cinchonia: the solution is always acid; when evaporated it lets fall small crystals on cooling, which are neutral and difficultly soluble. When, on the contrary, the solution is evaporated to dryness, a gum-like mass is obtained, which is resolved by cold water into a soluble superacetate, and an insoluble subacetate.

CARBONATE OF CINCHONIA. This salt is said to be precipitated from the solutions of cinchonia by carbonated alkalis, and moist cinchonia is stated to absorb carbonic acid from the air, and then to effervesce when dissolved in acids.

2. QUINIA. Quinia is obtained from *yellow bark* by a process precisely similar to that for procuring cinchonia from pale bark. But, as sulphate of quinia is abundantly prepared for medical use, that salt is a more ready source of the alkaloid: it is obtained by adding ammonia to a solution of the sulphate, when it falls in white flakes, which are apt, on drying, to become brown. Quinia is very difficult of crystallization, but it has been obtained in that form by very slowly evaporating its alcoholic solution by exposure to cold dry air. It may also be crystallized, according to Henri and Delondre (*Jour. de Pharm.*, xx., 157), by dissolving pure and crystallized sulphate of quinia in a large quantity of water, decomposing it by ammonia, washing the precipitate, dissolving it in weak alcohol, and adding water to the solution till it becomes milky: it is then left for some days exposed to the air, when portions of the separated quinia, which at first resembled fluid resin, gradually become crystalline, forming radiated and acicular groups, which are efflorescent. These crystals are *hydrate of quinia;* when heated they first soften, then become white and pulverulent, and, when fused, lose water; the fused quinia concretes into a resin-like mass, which, if cooled very slowly, shows signs of crystallization, and becomes negatively electric by friction: in water it gradually returns to the state of hydrate.

Quinia has a decided alkaline action upon proper tests; it is intensely bitter; very sparingly soluble, even in boiling water; readily soluble in boiling alcohol, which, when evaporated, leaves it in the form of a viscid mass: it is more soluble than cinchonia in ether. It forms distinct salts with the acids*. When heated in a tube it fuses, becomes thick, viscid, and dark-coloured, an oily liquid evaporates, ammoniacal and hydrocyanic vapours follow, and a bulky carbonaceous matter remains.

Anhydrous quinia consists of $({}_{20}car + {}_{12}h + {}_{2}o + n) = 162$; or,

				Pelletier and Liebig.	Göbel.	Brande †.
Carbon	20	120	74.0	74.39	72.28	73.80
Hydrogen	12	12	7.4	7.25	8.33	7.65
Oxygen	2	16	9.9	9.74	11.10	5.55
Nitrogen	1	14	8.7	8.62	8.29	13.00
Anhydrous Quinia	1	162	100.0	100.00	100.00	100.00

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[*] When quinia is obtained from the common varieties of yellow bark, it almost always contains more or less cinchonia: these alkaloids may be separated by solution in alcohol, which, when duly evaporated, deposits the cinchonia in crystals, while the quinia, being more soluble, remains in solution: by one or more repetitions of this process it may be freed from cinchonia: or they may be converted into *sulphates*, and then, the sulphate of quinia, being less soluble than the sulphate of cinchonia, crystallizes, and leaves the latter salt in solution.

[†] I insert my own analyses here, because they were made with much care at the time, and are singularly consistent

Sulphate of Quinia. This salt has excited great attention on account of its medicinal importance; its manufacture is chiefly carried on in Paris[*], though large quantities of it have occasionally been prepared in this country. The quinia is obtained from yellow bark, and dissolved in dilute sulphuric acid: the first crops of the salt are decoloured by animal charcoal; it is again crystallized, and very carefully dried: this operation requires care, for if the desiccation is carried too far, the salt loses its crystalline character, and crumbles down into powder.

The *sulphate of quinia*, as it occurs in commerce, is at present regarded as a subsalt, or a Disulphate, and is such, in reference to the above equivalent of quinia; but by some, an equivalent has been assumed which represents this as a neutral sulphate.

Disulphate of Quinia forms long acicular crystals, efflorescent, intensely bitter, and requiring about 740 parts of cold, and 30 parts of boiling, water, for their solution. They are soluble in 24 parts of cold alcohol (specific gravity 850), and much more soluble in boiling alcohol. This salt readily fuses, looking at first like melted wax, it then reddens, and begins to be decomposed; in the air it burns, producing at first a bulky charcoal, which, by continued heat, is consumed without residue; we are thus enabled to discover certain adulterations which are practised upon it[†]. It has the curious property of becoming luminous when heated to about 212°; its phosphorescence is increased by friction, and electricity is, at the same time, manifest.

The accurate determination of the composition of this salt, in its various states, is interesting and important; upon this subject there is some difference in the statements of different authors: the following, as given by Dumas and Baup, agrees with my own observations, but Liebig

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with the results of Pelletier, Dumas, and Liebig, as far as the carbon and hydrogen are concerned; in respect to the nitrogen, I cannot account for the discrepancy, or for the cause of the probable error in my own experiments. These analyses, which were published in the *Quarterly Journal*, vol. xvi., formed part of a paper which was intended for the Royal Society, and in which I first pointed out the existence of nitrogen as a characteristic element of the alkaloids then known. The paper was not read, and, on the arrival of the *Annales de Chimie*, containing Pelletier and Dumas' announcement of the same fact, it was withdrawn at the recommendation of the President.

[*] 120,000 ounces are annually exported from Paris. (Dumas.)

[†] The substances commonly employed for the adulteration of sulphate of quinia are, water, sugar, gum, starch, ammoniacal salts, and earthy salts, such as sulphate of lime and magnesia, or acetate of lime. Pure sulphate of quinia, when deprived of its water of crystallization by a heat of 212°, should lose only from 8 to 10 *per cent.* of water. Sugar may be detected by dissolving the suspected salt in water, and adding precisely so much carbonate of potassa as will precipitate the quinia. The taste of the sugar, no longer obscured by the bitter of the quinia, will generally be perceived; and it may be separated from the sulphate of potassa by evaporating gently to dryness and dissolving the sugar by boiling alcohol. Gum and starch are left when the impure sulphate of quinia is digested in strong alcohol. Ammoniacal salts are discovered by the strong odour of ammonia, which may be observed when the sulphate is put into a warm solution of potassa. Earthy salts may be detected by burning a portion of the sulphate. Several of the preceding directions are taken from a paper on the subject by Mr. Phillips. (*Phil. Mag. and Ann.*, iii., 111, and Turner's *Elements.*)

According to Dumas, *margaric acid* is sometimes mixed with sulphate of quinia; it is detected by its insolubility in dilute muriatic acid.

does not admit the existence of an anhydrous basic sulphate, which ought to consist of

				Baup.
Quinia	2	324	89	89.1
Sulphuric acid	1	40	11	10.9
Anhydrous disulphate of quinia	1	364	100	100.0

The ordinary sulphate of quinia, or the *crystallized disulphate*, consists of

				Dumas.
Quinia	2	324	74.3	74.6
Sulphuric acid	1	40	9.1	9.1
Water	8	72	16.6	16.3
Crystallized disulphate of quinia	1	436	100.0	100.0

When the salt effloresces, or when dried at 212°, it loses 4 atoms of its water, and when dried at 240° it loses 6 atoms, retaining 2, which, according to Baup, may be expelled by a higher temperature, but which are retained, according to Liebig, till the salt decomposes.

When the *disulphate of quinia* is triturated with dilute sulphuric acid, it first forms a white magma, which afterwards dissolves on adding more of the acid, and on evaporating this solution, or, if concentrated, on leaving it at rest, prismatic crystals of the *neutral sulphate* (according to our equivalent) are formed. This salt is much more soluble than the preceding, and at 212° it fuses in its water of crystallization; when dissolved in alcohol its solution yields crystals, which fall to powder on exposure to air. This sulphate, in crystals, is composed, according to Dumas, of

				Dumas.
Quinia	1	162	59.0	59.4
Sulphuric acid	1	40	14.6	14.3
Water	8	72	26.4	26.3
Crystallized sulphate of quinia	1	274	100.0	100.0

The various sulphates of quinia, therefore, may be thus represented:

	Symbols.	Equivalents.
1. Anhydrous disulphate	$= (2\,\text{Qui} + S')$	364
2. Crystallized disulphate	$= (2\,\text{Qui} + S' + 8\,q)$	436
3. Effloresced disulphate	$= (2\,\text{Qui} + S' + 4\,q)$	400
4. Do. dried at 240°	$= (2\,\text{Qui} + S' + 2\,q)$	382
5. Anhydrous sulphate	$= (\text{Qui} + S')$	202
6. Crystallized sulphate	$= (\text{Qui} + S' + 8\,q)$	274

Muriate of Quinia. $(\text{Qui} + mur'.)$ When dry quinia is exposed to a current of muriatic acid gas, it absorbs 18 *per cent.*, and forms a salt more soluble than the sulphate. (Liebig.) When quinia is dissolved in muriatic acid, the solution affords nacreous crystals, on evaporation, which are more soluble than sulphate of quinia, and less soluble than muriate of cinchonia: they contain about 7 *per cent.* of muriatic acid. (Pelletier and Caventou.) Probably, therefore, there are two muriates of quinia: regarding Liebig's salt as *anhydrous* it would consist of

				Liebig.
Quinia	1	162	81.5	81.9
Muriatic acid	1	37	18.5	18.1
Anhydrous muriate of quinia	1	199	100.0	100.0

Nitrate of Quinia. When quinia is dissolved in diluted nitric acid, and the solution evaporated, the nitrate separates in the form of an oil-like liquid, which gradually crystallizes. (Pelletier, Caventou, Dumas.)

Phosphate of Quinia is easily crystallizable: it forms acicular prisms, soluble in alcohol. (Pelletier and Caventou.)

Chlorate of Quinia, formed by dissolving quinia in chloric acid, yields, on evaporation, bundles of acicular prisms, which, when heated, fuse, and afterwards explode. (Dumas.)

Iodate of Quinia forms silky crystals. (Dumas.)

Arseniate of Quinia much resembles the appearance of the phosphate, but its crystals are less nacreous. (Pelletier and Caventou.)

Oxalate of Quinia. When a concentrated solution of oxalic acid is added to one of a soluble salt of quinia, a precipitate of oxalate of quinia falls; it dissolves in boiling water, and yields nacreous acicular crystals on cooling: it dissolves in excess of oxalic acid, and this solution also crystallizes in needles: the neutral oxalate is very soluble in alcohol, and the hot alcoholic solution deposits crystals on cooling.

Tartrate of Quinia resembles the oxalate, but is more soluble.

Tannate of Quinia. The infusion and tincture of galls precipitate quinia from its solutions: pure tannic acid produces a similar effect: the precipitate is soluble in acetic acid, and difficultly so in water.

Gallate of Quinia. Gallic acid occasions precipitates in all the solutions of quinia which are not very dilute: the alkaline gallates are yet more effective precipitants. Gallic acid unites directly with quinia, and the salt is difficultly soluble in cold water: its solution in boiling water becomes milky as it cools. The gallate of quinia is soluble in alcohol, and in excess of acid. (Dumas.)

Acetate of Quinia. The acetate of quinia, when slightly acid, is easily crystallizable: the solution, when evaporated to a certain point, forms a mass of distinct acicular crystals: when very slowly evaporated, it yields peculiar mamillary and stellated groups: it is not very soluble, and if coloured, it may be washed in water, and subsides in silky filamentous crystals: its concentrated solution, in boiling water, concretes into a crystalline mass when cold. (Dumas.)

3. Aricina. This alkaloid was discovered in 1829, by Pelletier and Coriol, (*Jour. de Pharm.*, xv., 575,) in a bark from Arica, which had been fraudulently mixed with cinchona: in appearance it resembles *yellow bark*, but we are unacquainted with its botanical history. Treated as usual for the separation of its alkaloid, it yields a substance much resembling cinchonia in its external characters, but differing from it materially in its aggregate chemical properties. It is insoluble in water, and nearly tasteless, but after a time, produces a biting sensation upon the palate: its acid solutions are very bitter; heated, it fuses like quinia, and is not volatile.

Its *sulphate* is not crystallizable from its aqueous solution, but yields a gelatinous mass, becoming horny when dried: its alcoholic solution, on the contrary, affords silky crystals, much like sulphate of quinia. When a few drops of sulphuric acid are added to its gelatinous sulphate, another sulphate, crystallizable in flattened prisms, is formed. The action of nitric acid on *aricina* is very distinct; when concentrated it produces with it a very deep green colour; when more dilute the colour is brighter, and when very dilute the solution is colourless: the production of this green colour is accompanied by a decomposition of the alkaloid, but, by using a very dilute acid for its solution, this is prevented, and a colourless nitrate obtained. According to Pelletier the ultimate components of aricina are

				Pelletier.
Carbon	20	120	70.5	70.9
Hydrogen	12	12	7.0	6.9
Oxygen	3	24	14.0	13.9
Nitrogen	1	14	8.5	8.3
Aricina	1	170	100.0	100.0

It is remarked by Dumas, that cinchonia, quinia, and aricina, may be regarded as oxides of a common radical or base, represented as follows:

$$(20\,car + 12\,h + n) + o = \text{Cinchonia.}$$
$$(20\,car + 12\,h + n) + 2\,o = \text{Quinia.}$$
$$(20\,car + 12\,h + n) + 3\,o = \text{Aricina.}$$

The atomic constitution of these, and of the preceding alkaloids, suggests many theoretical views, which, however, have not been sufficiently matured to merit a place here, and are essentially dependent upon the equivalents by which they are represented. The numbers which I have adopted represent these bodies as *niturets* of a compound radical, or as consisting of carbon, hydrogen, and oxygen + 1 atom of nitrogen; hence the notion of the existence in them of ammonia, to which, even their alkaline characters have been by some ascribed: Dumas compares them to urea, and regards them as amides; but these hypotheses are all unsatisfactory, and till our knowledge of the various hydrocarbons, and of their combinations, is much extended and simplified, we shall probably not be able to frame any correct theory, applicable to the ultimate constitution of these highly-interesting compounds.

4. CINCHONIC (KINIC) ACID. This acid, originally noticed by Hofmann, and by Vauquelin (*Ann. de Chim.*, lix., 162), is contained in the different species of *cinchona*, combined with lime, and with their alkaloids. It may be obtained by digesting an aqueous extract of cinchona in alcohol, which leaves a viscid mass containing cinchonate of lime: when this is dissolved in water, and exposed to spontaneous evaporation in a warm place, the salt of lime crystallizes, and these crystals, when purified, may be decomposed by sulphuric or oxalic acid, so as to abstract the lime, and separate the cinchonic acid: some add acetate of lead to the solution of cinchonate of lime, and decompose the precipitated cinchonate of lead by sulphuretted hydrogen, but the former methods are preferable. (Henry and Plisson, *Jour. de Pharm.*, xiii. and xv.; Liebig and Baup, *Ann. de Chim. et Phys.*, xlvii., 188, and li., 56.) When the cinchonic acid is separated its aqueous solution must be slowly and quietly evaporated, and it then yields crystals, soluble in 2.5 of water at 68°, and soluble also in alcohol: it tastes sour, but not in the least bitter. Sulphuric acid dissolves it, acquiring a green colour, and carbonizes it when heated. Heated with a little nitric acid, a crystallizable sublimate is at

first produced, which is analogous to *pyrocinchonic acid;* a larger addition of the acid converts it into oxalic acid. According to Baup, kinic acid consists of $({}_{15}car\ {}_{10}h+{}_{10}O)$, so that its equivalent is 180, or

				Baup.	Liebig.
Carbon	15	90	50.0	50.0	46.23
Hydrogen	10	10	5.5	5.6	5.89
Oxygen	10	80	44.5	44.4	47.88
Anhydrous cinchonic acid	1	180	100.0	100.0	100.00

The crystallized cinchonic acid includes 1 atom of water, its equivalent being 180 + 9 = 189*.

CINCHONATES OR QUINATES. In the *neutral cinchonates*, the oxygen in the acid is to that in the base as 10 to 1. They are soluble in water, but insoluble in absolute alcohol.

CINCHONATE OF LIME. $(\dot{C}+\dot{cin}'.)$ This salt crystallizes in transparent rhomboids, soluble in 9 parts of water at 60°, and much more soluble in hot water: when dried at 212° it loses 28 *per cent.* of water. Its equivalent in the *anhydrous* state, is 180 + 28 = 208, and in the *crystallized* state, including 10 equivalents of water, 208 + 90 = 298. According to Berzelius, a small quantity of cinchonate of lime may be extracted from the alburnum of fir-trees.

CINCHONATE OF COPPER $(Cu+\dot{cin}')$ is thrown down in the form of a difficultly-soluble green precipitate, when a soluble cinchonate is added to a solution of acetate of copper: the salt is not thrown down from sulphate or nitrate of copper. According to Baup, this is a basic salt.

CINCHONATE OF LEAD. $(Pl+\dot{cin}'.)$ The *neutral* salt forms acicular crystals, which, when gently heated, lose their water of crystallization. The *basic* salt is insoluble in water.

CINCHONATE OF SILVER $(Ag+\dot{cin}')$ is an anhydrous salt, which rapidly blackens by exposure to light.

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* CAHINCIC ACID. Under this name Pelletier and Caventou have described an acid procured from the cortical part of the cahinca root: the plant belongs to the Rubiaceæ, and grows in Brazil, being used for the cure of intermittents, dropsy, and other diseases. The acid is obtained by dropping muriatic acid into a decoction of the root; it is gradually deposited in small crystals. It is more perfectly procured by evaporating a strong alcoholic tincture of the cahinca root to dryness, dissolving the residue in water, precipitating by lime, and decomposing the calcareous salt which falls by oxalic acid: the cahincic acid must then be purified by recrystallization.

Cahincic acid requires 600 parts of water for its solution; it is very soluble in alcohol, and the solution, if saturated when hot, deposits the acid in tufts of crystals as it cools. Ether dissolves it as sparingly as water: it is intensely bitter. When heated, it softens, chars, and yields a white crystalline sublimate, which is not bitter, and contains no ammonia.

Cahincic acid is charred by sulphuric acid: with muriatic acid it forms a gelatinous compound, from which water throws down white flakes, which are not bitter: nitric and acetic acid produce very similar effects. With ammonia, potassa, lime, and baryta, it forms soluble neutral salts, which are not crystallizable, and from which the acids throw down cahincic acid. From Liebig's analysis (*Ann. de Chim. et Phys.*, xlvii., 186) this acid appears to consist of

Carbon	15	90	57.0
Hydrogen	12	12	7.6
Oxygen	7	56	35.4
Cahincic acid	1	158	100.0

But its equivalent has not been determined by experiment.

III. STRYCHNIA; BRUCIA; STRYCHNIC ACID. Strychnia was discovered in 1818, by Pelletier and Caventou. (*Ann. de Chim. et Phys.*, viii., 305, x., 142.) It is contained in many species of *strychnos*, especially in *S. nux-vomica*, *S. ignatia*, and *S. colubrina*. They also subsequently detected it in the celebrated Javanese poison, called *Upas-tieute*. (*Ann. de Chim. et Phys.*, xxvi., 44.) Strychnia is associated in the former sources with *Brucia*, a distinct alkaloid, which was originally detected in the bark of the nux-vomica tree, an article which was known in the drug-trade under the name of *spurious angustura bark;* and as the genuine angustura bark was presumed to be the bark of a species of *brucia*, the terms *brucine* and *brucia*, though evidently derived from a perfectly distinct source, have been applied to the alkaloid extracted, together with strychnia, from the bark of the *S. nux-vomica*. Brucia was discovered by the above chemists in 1819 (*Ann. de Chim. et Phys.*, xii., 118.) To them also we are indebted for our knowledge of the *strychnic*, or as they originally called it, *igasuric* acid, a term derived from the Malayan name of St. Ignatius' bean.

1 STRYCHNIA. Among the numerous processes which have been devised for the extraction of strychnia, the two following are the simplest: the first is suggested by M. Coriol, the second by M. Henry, junr., (*Jour. de Pharm.*, xi. 492., xvi. 752.)

Digest coarsely-powdered *nux-vomica* in repeated portions of cold water, till all soluble matters are extracted: carefully evaporate the infusions to the consistence of syrup, and precipitate by alcohol; wash the precipitate (which consists of gum,) with alcohol, and add the washings to the original portion, and evaporate the whole in a water-bath to the consistency of an extract: this consists almost entirely of strychnate of strychnia; dissolve it in cold water, which separates a little greasy matter; then heat the clear liquid, and add milk of lime so as to decompose the strychnate, and leave the lime in slight excess; drain, and dry the precipitate by pressure, and digest in boiling alcohol, which takes up strychnia, brucia, and some colouring-matter; these are obtained by evaporation, and may be separated by the action of weak alcohol, which dissolves the brucia and the colouring-matter, and leaves strychnia; wash it with a little dilute alcohol, and dissolve it in strong boiling alcohol; this deposits it in crystals on cooling.

Henry's process is as follows: the rasped or powdered nux-vomica is digested in warm alcohol, acidulated by sulphuric acid, as long as it dissolves anything; it is then pressed out, and powdered quick-lime is added to the alcoholic liquors to saturate the acid, and precipitate the colouring-matter: when this mixture has subsided, the clear part is poured off, the residue washed with alcohol, and these liquors filtered and distilled: they leave a brown alkaline residue, which is to be saturated by water slightly acidulated by sulphuric, muriatic, or acetic acid: the neutral liquor is then filtered off, concentrated by evaporation if necessary, and when cold precipitated by slight excess of ammonia; the precipitate is washed, and digested in warm dilute alcohol, to remove brucia; the remaining strychnia is then dissolved in boiling alcohol with a little animal charcoal, and filtered whilst hot: on cooling, the strychnia is deposited. (See Dumas, v., 754, for an abstract of the other methods.)

When a solution of strychnia in common alcohol is left to slow evaporation, it yields the alkaloid in octoëdra, or four-sided prisms, terminated by pyramids; when rapidly crystallized it is granular. It is intensely bitter, and extremely poisonous; one-eighth of a grain being sufficient to kill a dog, and a quarter of a grain often producing a decided effect upon a healthy man. It produces, in larger doses, paroxysms of tetanus, and repeated convulsions, like those resulting from electric shocks. Injected in very small quantities into the veins, death very soon ensues, and in this way it is, that the poisoned arrows of the Javanese produce their effect.

Strychnia is fusible, but not volatile, and easily decomposed by heat: subjected to destructive distillation it affords the usual products of these compounds. It is almost insoluble in cold water; and one part requires 2500 of boiling water for solution: the intensity of its bitterness is such, that its cold aqueous solution, which does not contain more than a six-thousandth of its weight of strychnia, may be diluted with 100 times its bulk of water, and yet remains sensibly bitter. It is soluble in common alcohol, but absolute alcohol, and ether, scarcely dissolve it when quite free from acid. It is soluble in the acids, and forms soluble, colourless, and crystallizable salts*. When chlorine is passed through a mixture of strychnia and water, it is dissolved, and the solution yields colourless crystals of muriate of strychnia by evaporation: boiled with iodine and water it is also dissolved. Fused with sulphur it evolves sulphuretted hydrogen. Adopting Liebig's analyses, strychnia is an anhydrous compound of

								Liebig.
Carbon	30	...	180	...	77.0	...	77.20
Hydrogen	16	...	16	...	6.8	...	6.72
Oxygen	3	...	24	...	10.2	...	10.13
Nitrogen	1	...	14	...	6.0	...	5.95
Strychnia	1		234		100.0		100.00

Hence we have 234 as the equivalent of strychnia, and its symbol $({}_{30}car + {}_{16}h + {}_{3}o + n.)$

SULPHATE OF STRYCHNIA. (STRY + s'.) This salt, when crystallized from its neutral solution, is in small cubes; excess of acid renders it acicular. It becomes opaque by exposure to air, without losing weight; it may be fused without decomposition when carefully heated; it then loses about 3 *per cent.* This salt is excessively bitter; it dissolves in about ten parts of water at 60°, and in less at 212°. According to Liebig it is anhydrous, and consists (dried at 212°,) of

					Liebig.
Strychnia	1	...	234	...	85.6
Sulphuric acid	1	...	40	...	14.4
Sulphate of strontia	1		274		100.0

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* Nitric acid always reddens strychnia, but it is said that *pure strychnia*, (that from upas,) is not thus discoloured, and that the effect is due either to a yellow uncrystallizable compound, which generally accompanies strychnia, or, to the presence of brucia. Be this as it may, the effect of nitric acid upon all the samples of strychnia and its salts, which I have examined, has been to redden them: we are, however, as yet, but imperfectly acquainted with this alkaloid and its combinations.

The other salts of strychnia are crystallizable, and mostly very soluble; even those with the oxalic and tartaric acids.

2. Brucia. The presence of this alkaloid in the usual sources of strychnia, and the method of separating them, have already been described. It is most abundantly procured from the bark of the *strychnos nux-vomica*, commonly called *false angustura.* This bark is coarsely powdered, and having been previously digested in sulphuric ether to free it from fatty matter, is treated by alcohol, the alcoholic solution evaporated, and the residue dissolved in water, saturated with oxalic acid, and evaporated to dryness. Alcohol, digested upon this residuum, dissolves colouring-matter, and leaves pure oxalate of brucia, which may be decomposed by lime, and the brucia dissolved out by boiling alcohol, from which, by slow evaporation, it is obtained in crystals.

Brucia forms either prismatic or foliated crystals, according as it has been slowly or rapidly deposited: it is soluble in about 850 parts of cold, and in 500 of boiling water; its taste is strongly and permanently bitter; it is very soluble in alcohol, but insoluble in sulphuric ether: with the acids it forms soluble salts, mostly crystallizable; they are bitter, and are decomposed not only by the alkalis, but by morphia and strychnia, both of which precipitate the brucia. Brucia is reddened by nitric acid, and the colour changes to violet on the addition of protochloride of tin. A drop of bromine added to the alcoholic solution of brucia, renders it violet; by these characters it is distinguished from strychnia and from the other alkaloids. Anhydrous brucia consists of

			Liebig.
Carbon	32	192	70.96
Hydrogen	18	18	6.50
Oxygen	6	48	17.40
Nitrogen	1	14	5.14
Anhydrous Brucia	1	272	100.00

Hence we have 272 as the equivalent, and $({}_{32}car + {}_{18}h + {}_{6}o + {}_{2})$ as the formula of brucia.

Crystallized Brucia is a perfectly definite hydrate, including 6 atoms of water; its equivalent therefore is $272 + 54 = 336$.

Sulphate of Brucia $(\text{Bru} + S')$ is very soluble in water, and sparingly so in alcohol; it forms prismatic crystals, which are extremely bitter, and include 4 atoms of water, 2 of which they lose by efflorescence.

The general characters of the remaining salts of brucia have been above stated.

3. Strychnic Acid. This acid was obtained by Pelletier and Caventou as follows: Powdered Ignatius' bean, or nux-vomica, was first digested in ether, and all soluble matters being removed, it was next treated by alcohol; the alcoholic solutions were evaporated, water added to the residue, and filtered; the filtered liquor was then digested with pure magnesia; an insoluble *strychnate of magnesia* was thus formed, which, washed with cold water and dried, was digested in alcohol to

abstract free strychnia; the strychnate of magnesia was then dissolved in boiling water, rapidly filtered, and mixed, whilst hot (for the salt is not soluble in cold water), with acetate of lead: the resulting *strychnate of lead* was then decomposed by sulphuretted hydrogen, and the sulphuret of lead being filtered off, or allowed to settle, the solution was evaporated; it yielded a brown liquid, which deposited hard granular crystals of *strychnic acid.* Neither the equivalent nor the ultimate composition of this acid have been satisfactorily determined.

STRYCHNATES. The *strychnates* of *ammonia*, *potassa*, and of *soda*, are very soluble both in water and in alcohol: when the aqueous solution of *strychnate of baryta* is evaporated, it yields spongy vegetations. The salts of iron, mercury, and silver, are not affected by neutral strychnate of ammonia, but it renders the solutions of copper green, and, after some time, a bright-green precipitate, scarcely soluble in water, falls: Pelletier and Caventou regard this character as distinctive of the strychnic acid.

IV. VERATRIA, AND OTHER ALKALOIDS. In this subsection I include a long list of alkaloids, and of other substances apparently related to them, which have been more or less accurately examined, but the greater number of which require more minute investigation. They are extremely interesting to the chemist from the analogy which they bear to the well-defined alkaloids; and to the medical physiologist, as presenting, in an insulated state, the active principles of many important and energetic articles of the *Materia Medica.*

1. VERATRIA. Veratria was discovered, in 1819, by Pelletier and Caventou (*Ann. de Chim. et Phys.*, xiv., 69), and, about the same time, by Meisner, in Germany. (Schweigger's *Jour.*, xxv., 377.) It is contained in the seeds of the *Veratrum sabadilla*, and the roots of the *Veratrum album*, or *white hellebore*, united with gallic acid*. It is most readily procured from the seeds of the *sabadilla*, which are first digested in ether, to remove oily matter, then boiled in alcohol, and the solution suffered to cool; it is then filtered, evaporated to dryness, and the residue digested in water; which, being partly evaporated, deposits a yellow matter, to be separated by filtration. The clear solution is now mixed with acetate of lead, which gives a precipitate, to be removed by filtering; and the filtered liquor (its lead having been separated by sulphuretted hydrogen, and heated) is now boiled with magnesia; the precipitate thus produced is digested in boiling alcohol, from which the veratria is deposited in a pulverulent form, on evaporation. If not at first white, it may be rendered so by a second solution, and by the aid of animal carbon. As thus procured, veratria is not crystallizable; it has a pungent, but not a bitter taste, and powerfully irritates the nostrils. A very small dose produces nausea and vomiting. It fuses at a temperature of 122°, and concretes, on cooling, into a translucent yellow mass. Boiling water does not take up more

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* Veratria has also been discovered in the bulb of the *Colchicum autumnale*, or *meadow saffron*, and is probably the principle to which the curative powers of that drug, in cases of gout, are referable. It is curious that, many years ago, Mr. Moore suspected the active ingredient in the celebrated French gout-specific, called *Eau Medicinale d'Husson*, and which is a vinous infusion of colchicum, to be derived from hellebore, which we now know to contain the same alkaline base as colchicum.

than a thousandth part of its weight, but it is readily soluble in alcohol, and less so in sulphuric ether. But in this state, veratria, according to Couerbe (*Ann. de Chim. et Phys.*, lii., 352), is still blended with other principles, two of which are abstracted by boiling water: of these, one is crystallizable, and termed *sabadilline;* the other is deposited on the evaporation of the mother-liquor in the form of viscid drops of a reddish colour and acrid taste: he has termed it *resinigomme de sabadilline**. The alkaline residue of the veratria remaining after this treatment, is digested in successive portions of ether, and when these ethereal solutions are spontaneously evaporated, they deposit a white viscid matter, which is now *pure veratria:* the matter which resists the action of ether, is called, by Couerbe, *veratrin.* Pure veratria consists, according to Couerbe, of

			Couerbe.
Carbon	34	204	71.24
Hydrogen	22	22	7.52
Oxygen	6	48	16.39
Nitrogen	1	14	4.85
Veratria	1	288	100.00

The equivalent, therefore, of veratria is 288, and its formula $({}_{34}car + {}_{22}h + {}_{6}o + n.)$

SALTS OF VERATRIA. Veratria forms compounds with the acids, which are very difficult of crystallization. Couerbe succeeded in obtaining a crystallizable *sulphate of veratria* $(\text{Ver} + S')$, from the analyses of which he established the equivalent of veratria as above. The *muriate of veratria* is also a crystallizable salt.

2. ATROPIA. The existence of an alkaloid in the *Atropa belladonna*, or *deadly nightshade*, was first shown by Brandes, in 1819 (Schweigger, *Jour.*, xxviii.), and the process for obtaining it was afterwards improved by Mein (*Jour. de Phar.*, xx., 87), in consequence of Runge's discovery of the destructibility of some of these bases by the fixed alkalis.

I must refer the reader to Mein's process and to Dumas (*Chim. App. aux Arts*, v., 804) for the details. The root of the plant, dried and powdered, is the part employed, and is said to yield not more than a three-thousandth part of pure atropia.

Atropia crystallizes in white silky prisms: it is soluble in anhydrous alcohol and in ether, and in about 500 parts of cold water; this solution is bitter, and when dropped into the eye, dilates the pupil.

Atropia forms definite compounds with the acids; the sulphate and acetate are more crystallizable than the muriate or nitrate: the salts are decomposed, and the atropia thrown down by potassa and ammonia, by infusion of galls, and by chlorides of gold and platinum, with which it forms compounds gradually crystallizing, and probably composed of muriate of atropia combined with the metallic chloride.

When atropia is heated with potassa it is easily decomposed, and abundance of ammonia is evolved. The facility with which this alkaloid is thus destroyed, renders the use of caustic alkalis in its preparation inadmissible. According to Liebig, the ultimate composition of atropia is $({}_{68}car + {}_{23}h + {}_{12}o + n)$, but the nature and properties of this body require further examination.

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* From the oil of the seeds of sabadilla, Pelletier and Caventou obtained, by the process of saponification, a peculiar fat-acid, which they termed *cevadic acid.*

3. Hyoscyamia. This alkaloid was obtained by Brandes from the seeds of the *Hyoscyamus niger;* an alcoholic solution or tincture of which was mixed with a small quantity of lime, and the precipitate digested in dilute sulphuric acid; the solution, containing sulphate of hyoscyamia, is then decomposed by the addition of powdered carbonate of soda; the hyoscyamia is thus precipitated, and it is quickly removed from the solution and dried by pressure in blotting-paper; it is then dissolved in absolute alcohol, filtered through animal charcoal, and the solution evaporated, a little water being added towards the end of the process.

Hyoscyamia is described as forming silky crystals, difficultly soluble in water, of an acrid and nauseous taste, highly poisonous, and, when applied to the eye, producing a dilated pupil. It is easily decomposed, with the evolution of ammonia, by the fixed alkalis. It is very soluble in alcohol and ether: its salts are said to be neutral and crystallizable. (Geiger and Hesse, *Jour. de Pharm.*, xx., 92.)

4. Solania. This alkaloid was discovered by Desfosses of Besançon, in the berries of the *Solanum nigrum*, and in the leaves of the *Solanum dulcamara.* (*Jour. de Phar.*, vi. and vii.) The filtered juice of the ripe berries was saturated by solution of ammonia, which threw down a gray powder: this was dissolved in boiling alcohol, filtered through animal charcoal, and evaporated, when the solania was deposited. Solania is white and pulverulent, and, though like most of these substances, it has no direct alkaline action upon turmeric, it restores the blue of reddened litmus. Acted on by caustic potassa it evolves ammonia. It is precipitated from its acid solutions by the alkalis, and does not form crystallizable salts. It has been analyzed by Blanchet, who states its components to be *per cent.* 62 carbon, 8.9 hydrogen, 1.6 nitrogen, and 27.5 oxygen. Upon the whole, our information upon the subject of solania is very incomplete.

5. Daturia. Daturia was discovered by Brandes in the seeds of the *Datura stramonium.* Geiger and Hesse obtained it by the same process as that for procuring hyoscyamia. (*Jour. de Phar.*, vi., and xx.) The following process is given by Simes, for its extraction. A pound of stramony seeds, in fine powder, was boiled for an hour in 3 quarts of weak alcohol; to the liquor, filtered whilst hot, half an ounce of magnesia was added, and the mixture shaken from time to time for 24 hours; the precipitate was then collected, boiled for some minutes with 12 ounces of alcohol, and filtered through animal charcoal; this alcoholic solution was then evaporated to half its bulk, and set aside for 24 hours, when it was found to have deposited globules of oil and crystals of colourless daturia; this deposition continued during the spontaneous evaporation of the liquor, when the daturia was collected, dissolved in acidulated water, filtered through charcoal, precipitated by magnesia, again dissolved by alcohol, and obtained in a pure form. Daturia crystallizes in colourless quadrangular prisms, of a bitter and acrid taste, and is very poisonous; applied to the eye, the pupil is durably dilated. Its aqueous solution is decidedly alkaline. It is soluble in about 280 parts of cold, and 72 of boiling, water, and readily soluble in alcohol.

THE SALTS OF DATURIA are generally soluble, crystallizable, and permanent in the air; they are decomposed by the alkalis, and daturia falls in white flocculi. Dumas, adverting to the analogy that subsists between daturia, atropia, and hyoscyamia, suggests the possibility of their identity: their ready decomposition by the fixed alkalis, approximates them to the ammides; and it seems probable that a more accurate knowledge of their ultimate composition may throw light upon the subject of the alkaloids in general.

6. PICROTOXIA. This name has been given to a poisonous bitter substance, discovered by Boullay, in 1819, in the berries of the *Menispermum cocculus*, or *Cocculus indicus.* It may be obtained by the following process: Add acetate of lead to a decoction of the berries, as long as any precipitate falls; filter, evaporate, and digest the extract in highly-rectified alcohol; evaporate to dryness, and agitate the remaining matter with a little water; the picrotoxia remains in the form of white prismatic crystals of a bitter taste.

Picrotoxia is difficultly soluble in water. Alcohol, of the specific gravity of .810, dissolves one-third its weight. It is soluble in weak solutions of the pure alkalis. Picrotoxia was originally described by Boullay as a salifiable base, and as united in the seeds to a peculiar acid, which was termed *menispermic acid.* Casaseca has shown that this acid is a mixture of malic and sulphuric acids, and that picrotoxia has no alkaline reaction, and does not neutralize the acids; but it certainly appears to form definite compounds with the acids, some of which are crystallizable. Its ultimate composition has not been accurately ascertained; but, according to Opperman, it does not contain nitrogen, but consists of 61.5 carbon, 6.1 hydrogen, and 32.4 oxygen *per cent.*

7. NICOTINA. This principle was obtained by Vauquelin, by the following process (*Ann. de Chim.*, lxxi.): Evaporate the expressed juice of fresh tobacco-leaves to one-fourth its bulk; and, when cold, strain it through fine linen; evaporate nearly to dryness; digest the residue in alcohol; filter and evaporate to dryness; dissolve this again in alcohol, and again reduce it to a dry state. Dissolve the residue in water, and saturate the acid which it contains with weak solution of potassa, introduce the whole into a retort, and distil to dryness; redissolve, and again distil three or four times successively. The nicotin will thus pass into the receiver, dissolved in water, from which solution it may be obtained by very gradual evaporation; or it may be saturated by sulphuric acid, and the sulphate of nicotina, so formed, decomposed by the addition of lime and distillation; a mixture of nicotina, ammonia, and water, passes over, from which the nicotina may be abstracted by agitation with ether, and this ethereal solution, when distilled, leaves the nicotina.

Nicotina, in its purest state, is a transparent colourless liquid, of a pungent and disagreeable odour, and acrid taste: it is alkaline; volatile at 212°; soluble in all proportions in water, alcohol, and ether, and, when its aqueous solution is agitated with ether, the greater part of it leaves the water, and is retained by the ether. It is very poisonous, and forms distinct salts with the alkalis. It has been but imperfectly examined, and, from the method of obtaining it, it appears doubtful whether it is an original proximate principle of tobacco.

8. Conia. It appears from the experiments which have been made upon hemlock, that its active principle resides in a volatile and uncrystallizable alkaloid: its properties have been investigated by Boutron-Charlard, and O. Henry. (*Ann. de Chim. et Phys.*, lxi., 337.) The activity and importance of hemlock, as a medicine, renders a further examination of it highly desirable.

9. Aconita. This is an extremely poisonous and active alkaloid, extracted from the aconite; it is probably contained in several species of that plant. Its properties and combinations are as yet imperfectly known, and its ultimate composition has not been ascertained.

10. Digitalia. Leroyer gives the following directions for the extraction of digitalia: He takes "one livre of digitalis purpurea, and first treats it with cold ether, and then with the same agent heated in a close stove, in order that the temperature may be more easily raised. The tinctures obtained in this manner, were, after filtration, of a greenish-yellow colour and a bitter taste; the residue from their evaporation has a resinous appearance, and is insupportably bitter, producing upon the tongue a sensation of numbness like that which is experienced from chewing aconite. Exposed to the air, this residuum powerfully absorbs moisture. When taken up by distilled water, it divides into two parts; the vehicle holds one of them in solution, the other is precipitated, and presents all the characters of chlorophylle; the aqueous solution of the ethereal residue reddens turnsol paper. Hydrate of protoxide of lead was then added to neutralize the free acid thus indicated, and to separate from the bitter principle that which is apparently combined with it. The salt of lead thus formed was soluble, and consequently could not be separated from the bitter principle; several earths were tried for the same purpose, but with no better success; it was therefore necessary to resort to another method. After evaporating to dryness the portion treated by the lead, it was again dissolved in highly-rectified ether; by this operation he obtained the bitter principle of digitalis disengaged from those substances with which it was united. By evaporating this solution a brown heavy substance is obtained, that restores, though slowly, the blue of turnsol-paper reddened by an acid. If in this last mentioned character, observes M. Leroyer, as well as in its bitterness it approaches the alkaloids, its extreme deliquescence separates it from them. This deliquescence prevents it from crystallizing in a distinct and permanent manner; but M. Leroyer thinks that it does crystallize regularly under favourable circumstances. Dr. Prevost having placed a drop of the solution of digitaline in alcohol on a piece of glass, and cautiously evaporated it by means of a spirit-of-wine lamp, detected with a microscope numerous and well-defined crystals of various forms. The same observer states, that the basic form of them all appeared to be a straight prism with rhomboidal base."

11. Delphia. This alkaloid was discovered, in 1819, by Lassaigne and Feneulle, in the seeds of the *Delphinium staphysagria*, or *Stavesacre*. (*Ann. de Chim. et Phys.*, xii., 358.) The simplest mode of obtaining it is that suggested by Berzelius: digest the bruised seeds in water acidulated by sulphuric acid, then add magnesia, collect and dry the precipitate, and digest it in alcohol, by which the delphia is taken up: it may be purified by boiling it in the state of sulphate, with animal charcoal, and

precipitating by ammonia, which throws it down in a gelatinous form: obtained by evaporating its alcoholic solution, it is a crystalline powder, which becomes opaque when dried.

Delphia, when pure, is very difficultly soluble in water at any temperature: it is soluble in alcohol, and somewhat less so in ether. It has a peculiarly acrid taste, and excites a burning sensation in the throat. Its salts are very pungent and bitter, and most of them very soluble. Delphia has been analyzed by Couerbe (*Ann. de Chim. et Phys.*, lii., 359), with the following results:—

			Couerbe.
Carbon	27	162	77.00
Hydrogen	19	19	8.89
Oxygen	2	16	7.50
Nitrogen	1	14	6.61
Delphia	1	211	100.00

Couerbe discovered another principle in the stavesacre-seed, which he has termed *Staphisain;* in ultimate composition it appears to resemble the alkaloids, but it is not salifiable It is separable from delphia by the action of ether, in which it is insoluble.

12. CORYDALIA. This alkaloid was discovered by Wackenroder in the *Corydalis tuberosa*, (*Phil. Mag.* and *Ann.*, iv., 153.) It is contained in the plant, in combination with malic acid, from which it may be separated by magnesia, and purified by solution in alcohol. It forms prismatic crystals, soluble in alcohol and ether, but very sparingly so in water; it is tasteless, but its salts are bitter; they are decomposed by the alkalis, and by infusion of galls.

13. SANGUINARIA. The root of the *Sanguinaria canadensis*, or *Blood root*, contains, according to Dana (*Phil. Mag.* and *Ann.*, v., 151), an alkaloid, which may be separated as follows: the red alcoholic tincture of the powdered root is mixed with a little ammonia, and poured into water; the matter which subsides yields the alkali to hot alcohol: it must be purified by animal charcoal. It is white, acrid, insoluble in water, but soluble in alcohol and ether, and alkaline to tests. Its salts have a red colour.

14. CYNAPIA. Under this name an alkaloid, obtained from the *Æthusa cinapium*, has been described by Professor Ficinus, of Dresden. It forms prismatic crystals soluble in water and alcohol, but insoluble in ether: it is salifiable.

15. EMETINA. This term implies the active or emetic principle of *Ipecacuanha*, from which it was procured by Pelletier and Majendie, in 1817. Boullay has since detected it in the root of the *Violet* (*Viola odorata*), and Torreri in the root of the *Iris florentina.*

Emetina is obtained by digesting powdered ipecacuanha root, first in ether, by which a fatty matter is abstracted (which gives ipecacuanha its nauseous odour, but which is not emetic), and then in alcohol: this tincture is mixed with magnesia, which throws down impure emetina: the deposit is washed with cold water, and redissolved in boiling alcohol, from which solution the emetina is obtained by evaporation or distillation. Berzelius proposes to digest the powdered root in dilute sulphuric acid, precipitate by magnesia, and separate the emetina by alcohol as before; but this process has not, I believe, been adopted. Emetine is a yellow uncrystallizable substance, of a bitter taste, fusible at about 125°, almost insoluble in cold water and in ether, but soluble in alcohol: it has an alkaline reaction, but its salts have not been satisfactorily crystallized. It is powerfully emetic. The French chemists have given the name *Violine* to the emetine of the violet-root. According to Caventou, the emetic action of emetine is prevented by infusion of galls, and the *gallate of emetina* is insoluble*.

§ XIX. Crystallizable and other Principles, not salifiable, but in some respects analogous to the Alkaloids.

1. Salicin. This substance was extracted, in 1830, from the bark of the willow (*Salix helix*), by M. Leroux. It exists in several species of willow; and, according to Braconnot, in the bark of the poplar, especially the *Populus tremula*†.

It is obtained by adding subacetate of lead to a decoction of willow-bark, as long as a precipitate falls, filtering, boiling with chalk, filtering a second time, and evaporating the solution, when the salicin crystallizes.

Salicin forms white prismatic crystals, of a bitter taste, insoluble in ether, sparingly soluble in cold, but readily so in hot water and alcohol; it is neither acid nor alkaline, and when heated with sulphuric or muriatic acid, is converted into an insoluble matter, having the characters of a resin. By the action of nitric acid, it is said to be converted into carbazotic acid; but according to the analyses of Pelouze and J. Gay Lussac, it is a ternary compound of 55.49 carbon, 6.38 hydrogen, and 38.13 oxygen. We have no means of determining its equivalent.

2. Piperin. This substance was discovered by Oersted, in 1819 (*Journal de Phys.*, xc.), and afterwards examined by Pelletier; it is obtained from *black pepper*, (*Ann. de Chim. et Phys.*, xvi.) Vogel gives the following process for its extraction: Digest 16 ounces of coarsely-powdered pepper for forty-eight hours in twice its weight of water, five times in succession; press out and dry the insoluble portion, and digest it for three days, in 24 ounces of alcohol; press out this solution, filter, and evaporate it to the consistence of syrup: crystals are deposited, which are to be freed from adhering resin by ether, redissolved in alcohol, purified by animal charcoal, and recrystallized.

Piperin is a crystallizable substance, generally of a pale straw-colour, and in the form of four-sided prisms, insoluble in cold, and slightly

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* Several analyses have been made of different species of ipecacuanha (and there are several known in the drug-trade), by MM. Pelletier and Majendie, and an account of their researches is published by M. Robiquet (*Ann. de Chim. et Phys*, iv. 172); 100 parts of the brown wrinkled variety of this root, deprived of the comparatively inert woody fibre which traverses its centre, afforded

Fatty matter	2
Emetine	14
Gum	16
Starch	18
Woody fibre	48
A trace of wax	
Loss	2
	100

† Described, from this source, under the name *Populin*?

soluble in hot water; readily soluble in alcohol, and less so in ether. It fuses at a little above 212°. It dissolves in, but does not combine with, the acids: dissolved in acetic acid, it is left, on evaporation, in plumose crystals. It consists, according to Göbel, of 80.95 carbon, 8.13 hydrogen, and 10.92 oxygen.

3. Asparagin. This principle was discovered in asparagus, by Vauquelin and Robiquet (*Ann. de Chim.*, lvii.); and was shown by Plisson to be identical with a substance found by Robiquet in liquorice-root, which he named *Agedoite* (*Ann. de Chim.*, lxxii.), and also with the *Althein*, discovered by Bacon, (*Ann. de Chim. et Phys.*, xxxiv.) It has been found by Link in the *Ornithogalum*, and by Blondeau in the *Symphytum officinalis.*

It is best obtained from asparagus, the juice of which is expressed, evaporated to the consistency of syrup, and set aside; it deposits crystals, which are purified by solution in water and recrystallization.

Asparagin forms transparent prismatic crystals, which are hard, brittle, of a cooling and somewhat nauseous taste, neither alkaline nor acid; soluble in 58 parts of cold water, and more soluble in hot; insoluble in anhydrous alcohol, and in ether. The crystals lose about 12 *per cent.* of water when heated: they evolve ammonia when triturated with caustic potassa, and nitric acid converts them into a bitter matter. According to Liebig, *anhydrous* asparagin consists of

				Liebig.
Carbon	8	48	36.4	36.74
Hydrogen	8	8	6.0	5.94
Oxygen	6	48	36.4	36.05
Nitrogen	2	28	21.2	21.27
Anhydrous asparagin	1	132	100.0	100.00

The *crystals* include 2 atoms of water.

Aspartic Acid. When asparagin is long boiled with hydrated oxide of lead, magnesia, or other bases, it is resolved into ammonia, and into a new acid, called the *aspartic acid*, and yet asparagin is not, as might be supposed, an *aspartate of ammonia*, because the alkalis do not immediately separate ammonia from it, nor do acids throw down aspartic acid when added to its aqueous solution.

When the *aspartate of lead* is decomposed by sulphuretted hydrogen, the *aspartic acid* is separated in the form of a white crystalline powder, consisting of 1 atom of anhydrous acid and 2 of water. The *anhydrous* aspartic acid consists of

				Liebig.
Carbon	8	48	41.7	42.16
Hydrogen	5	5	4.4	4.37
Oxygen	6	48	41.7	41.27
Nitrogen	1	14	12.2	12.20
Anhydrous aspartic acid	1	115	100.0	100.00

Hence we see that 1 atom of anhydrous asparagin = 132, contains the elements of 1 atom of aspartic acid = 115, and 1 of ammonia = 17: or

$$\overset{\text{Asparagin.}}{(8\,car + 8\,h + 6\,o + 2\,n)} = \overset{\text{Aspartic acid.}}{(8\,car + 5\,h + 6\,o + n)} + \overset{\text{Ammonia.}}{(3\,h + n.)}$$

4. DAPHNIN. The existence of an acrid crystallizable principle in mezereon (*Daphne mezereon*), was first shown by Vauquelin (*Ann. de Chim.*, lxxiv.), and afterwards its properties were further examined by C. G. Gmelin and Bär, in 1822. A decoction of mezereon-bark is precipitated by subacetate of lead, and the washed precipitate decomposed by sulphuretted hydrogen: the solution is then filtered, evaporated, and the residue digested in cold anhydrous alcohol, from which daphnin crystallizes, leaving malic acid and colouring-matter.

Daphnin, purified by washing with cold alcohol, solution in water, and recrystallization, forms colourless crystals, bitter, but neither alkaline nor acid; soluble in hot, and sparingly in cold water, soluble in alcohol and ether, converted into oxalic acid by nitric acid, and fusible, before it decomposes by heat.

5. CAFFEIN. *Coffee* has been the subject of many chemical researches, and in 1821 a peculiar crystallizable principle was extracted from it by Pelletier and Caventou, and by Robiquet and Runge, previous to which, Schrader had published an analysis of *coffee-beans*, of which the following is an abstract. (Berzelius, *Lehrbuch*, iv.) He found that 8 ounces of *raw coffee* distilled with water, gave a turbid and odorous distilled water, but the quantity of oil which probably produced these effects, was too small to collect. The decoction in the retort was filtered, and was then of a yellow-green colour: it was evaporated to syrup-consistence, and mixed with alcohol, sp. gr. 0.85, as long as this occasioned a precipitate. The filtered solution was then evaporated, and left 17.58 *per cent.* of a brown transparent extract, (Gmelin's *coffee-bitter*,) soluble in water, and having the characteristic bitter taste of the raw coffee-bean. It is insoluble in ether and in absolute alcohol, and sparingly soluble in alcohol of 0.84, but its aqueous solution is not precipitated by alcohol. It is not altered by dilute acids or alkalis; the last deepen its colour, and lime-water precipitates it of a green colour: the salts of iron produce with it a grass-green colour, and a dark-green precipitate falls, soluble in excess of acid. When an alkali is added to its solution, previously mixed with a salt of copper, a fine green precipitate falls, which, carefully prepared without excess of oxide of copper, may be used as a pigment. Acetate of lead precipitates it yellow-green, and protochloride of tin, gray; and when these precipitates are decomposed by sulphuretted hydrogen, the extractive is evolved unchanged. It is neither precipitated by gelatine nor by infusion of galls. It yields ammonia on destructive distillation, and a crystallized sublimate.

The substance precipitated by the addition of alcohol to the original decoction of the coffee, was a mixture of 3.6 *per cent.* of brown gum, and 37 pulverulent extractive. The coffee-beans also contain resin, and a fat oil, which may be extracted by alcohol. The insoluble residue constituted two-thirds of the weight of the beans. When burned, coffee-beans leave 4 *per cent* of ash, consisting of carbonate of potassa, (the base of which was combined with a vegetable acid,) sulphate of potassa, chloride of potassium, carbonate and phosphate of lime, magnesia, and the oxides of iron and manganese.

The crystallized sublimate alluded to by Schrader has since become the subject of separate examination; it is the *caffein* of Pelletier and others, and was first obtained by Runge in 1820. There are various methods of obtaining it, and it may be procured in considerable quantity by those who roast large quantities of coffee; it sublimes in a very impure form, but is easily deprived of its adhering impurities. The process generally recommended for its preparation is that of Runge; it consists in making a strong aqueous infusion of ground raw coffee, adding to it a solution of sugar of lead, which occasions a green precipitate, and leaves the supernatant liquor colourless: the excess of the salt of lead in this liquor is then precipitated by sulphuretted hydrogen, it is filtered, and evaporated; the caffein remains, and must be treated by animal charcoal to whiten it, and recrystallized.

Caffein forms white silky crystals, soluble in boiling water and alcohol, and deposited in crystalline filaments as these solutions cool; it has no alkaline reaction, nor does it saturate acids; it is, therefore, not an alkaloid; yet it resembles those bodies in ultimate composition, consisting, according to Pfaff and Liebig, (*Ann. de Chim. et Phys.*, xlix. 303,) of

Carbon	8	48	49.5
Hydrogen	5	5	5.1
Oxygen	2	16	16.5
Nitrogen	2	28	28.9
Caffein	1	97	100.0

Roasted Coffee. According to Cadet (*Ann. de Chim.*, lviii.), coffee roasted to a pale-brown colour, loses 12.3 *per cent.;* to a chestnut-brown, 18.5 *per cent.*, and to a black, 23.7 *per cent.* So that the ordinary loss of weight in coffee-roasting may be estimated at about 12 to 14 *per cent.* Schrader found, in roasted coffee,

Extractive matter soluble in water and alcohol, closely resembling that of raw-coffee, but browner and deliquescent	12.5
Brown gum	10.4
Extractive, soluble in water, but insoluble in alcohol	5.7
Oil and resin	2.0
Insoluble burned woody fibre	69.0
	99.6

When roasted coffee was distilled with water, the aroma passed over; the distilled water reddened litmus, and had the agreeable odour of the coffee. When raw coffee is so roasted as to collect the volatile products, a portion of fragrant empyreumatic oil passes over, which, in the ordinary mode of roasting, is lost. According to Chevenix, (Tilloch's *Magazine*, xii. 350,) a portion of tannin is formed during roasting; and Cadet states, that the greatest proportion of tannin is contained in slowly and slightly-roasted coffee, and that when it is very brown or black, its proportion is much diminished. This product, however, probably depends much upon temperature, for Payssé, Schrader, and Runge, assert that gelatine is not precipitated by an infusion of roasted coffee. Schrader endeavoured to ascertain the particular principle to which the flavour and aroma of roasted coffee are due, by exposing each of the proximate principles of unroasted coffee separately to heat; but he found that no one of them yielded any peculiar flavour, and that the ligneous residue, when roasted, acquired as much of the characteristic flavour, as when the other principles were retained; so that the flavour of roasted coffee must be ascribed to the joint effect upon all the constituents: the caffein seems to play a very passive part as far as flavour is concerned, and a considerable proportion of it remains unchanged, after roasting, whilst another part of it is merely volatilized.

The flavour of coffee as a beverage, depends in the first place upon the *roasting*, and in the next, upon the mode of *making* the infusion; the coffee should be rapidly but well roasted, and it is said to be improved by roasting in a close vessel; it should be aired and ground into fine powder immediately before use; it is sometimes *boiled*, and sometimes *infused*; in the former case, the coffee is darker coloured, more bitter, and has more of an acid flavour than when infused, and the infusion in a close vessel is more aromatic than that in an open one, especially when the coffee-pot is so managed as to *steam* the powder. The pleasantest flavour is obtained by placing a *sufficient quantity* of finely-ground and freshly-roasted coffee upon a filter, (very coarse filtering paper in a funnel answers very well,) and pouring boiling water upon it so as to filter quickly into the vessel beneath. When coffee is boiled it is apt to be thick, unless fined by the addition of a little white of egg, or isinglass, which probably carries down the tannin.

6. CATHARTIN. *a.* Lassaigne and Feneulle, in their analysis of *senna-leaves*, (*Jour. de Phar.*, x. 59,) obtained from them a little volatile oil, having the nauseous odour of the infusion of senna. A cold infusion of senna contains vegetable albumen. From a decoction of senna precipitated by acetate of lead, decomposed by sulphuretted hydrogen, and subjected to the action of several other solvents, they obtained a bitter purgative principle, which they called *cathartine;* but from the complexity of the process, it seems doubtful how far the product is to be regarded as a real proximate principle of senna: the whole subject requires revision. The effects of various reagents upon an infusion of senna, are detailed by Mr. Batley in the *London Medical Repository*, (xv. 169.)

7. COLOCYNTIN, or the purgative principle of the pith of coloquintida, was extracted by Vauquelin from that substance by the action of alcohol, which left on evaporation a resin-like matter, difficultly soluble in water, readily soluble in alcohol and in acids and alkalis, and eminently bitter and purgative.

8. ELATIN. The fruit of the *wild cucumber* (*Cucumis elaterium*) furnishes a very acrid juice, which deposits the powerful cathartic known under the name of *elaterium.* This substance occurs in commerce in thin cakes of a greenish colour and bitter taste; it derives its cathartic powers from a small portion of a very active principle, which Dr. Paris has called *Elatin.* (*Pharmacologia.*) From 10 grains of elaterium, he obtained,

Water	0.4
Extractive	2.6
Fecula	2.8
Gluten	0.5
Woody matter	2.5
Elatin Bitter principle	1.2
	10

By boiling elaterium in alcohol, distilling off the greater part of the solvent, and setting the remainder aside to evaporate spontaneously, Mr. Hennell obtained a *green resin*, in which the purgative quality resides, and a crystallized substance; he separated these by the action of ether, which took up the resin and left the crystallized product; the latter was purified by solution in hot alcohol and crystallization: it was nearly insoluble in water and in ether, but soluble in hot alcohol, bitter, fusible at about 350°, neither acid nor alkaline, and composed of 36.9 carbon, 23.9 hydrogen, and 39.2 oxygen *per cent.* In elaterium, Hennell found 40 *per cent.* of the crystallizable matter, and 21 of the purgative resin, the residue being lignin, starch, and earthy matter. (*Jour. R. Inst. N. S.*, i. 532.)

9. Rhabarbarin. The purgative principle of rhubarb is stated by Nani, of Milan, to be an alkaloid, but the details of his experiments have not been given. (*Quart. Jour.*, xvi. 172.)

The root of rhubarb (*Rheum palmatum*,) as it occurs in commerce, has been examined by Schrader and myself with the following results.

Water	8.2
Gum	31.0
Resin	10.0
Extract, Tan, and Gallic acid	26.0
Phosphate of lime	2.0
Malate of lime	6.5
Woody fibre	16.3
(Brande, *Quart. Jour.*, x. 291,)	100.0

Resin	2.8
Rhabarbarin	24.0
Mucilage	14.8
Woody fibre	47.0
Oxalate of lime	9.0
Loss	2.4
(Schrader, *Gmelin's Handbuch*,)	100.0

10. Rhein. When 1 part of powdered rhubarb is gently heated with 8 of nitric acid, sp. gr. 1.37, and the liquor evaporated to the consistence of syrup, and diluted with cold water, an orange-coloured powder is deposited, which M. Vaudin has termed *Rhein*; it is inodorous, bitter, sparingly soluble in cold water, soluble in alcohol, ether, and boiling water, reddened by the alkalis, and rendered paler by the acids. It is stated not to be a *product*, but to pre-exist in rhubarb, and to be extracted from the root by ether: it requires re-examination.

11. Rhaponticin is a substance obtained from the *Rheum rhaponticum*, in the form of yellow scales, inodorous, insipid, and insoluble in cold water; soluble in 24 parts of boiling water, and in 2 of anhydrous alcohol. (Hornemann.)

12. Gentianin. This principle has been extracted by the following process from the root of the *Gentiana lutea*[*], by Henry and Caventou. (Majendie's *Formulary*, translated by Gregory.)

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[*] Many other bitter substances have been described as distinct *proximate principles*, but their title to that character is so doubtful, that I have here omitted their enumeration. They generally partake of the above-described characters either of gum, resin, or extractive. *Hops* contain a bitter extractive matter, which has been termed *lupulin*, a name first applied by Dr. Ives, of New York, to the pollen, or *condition* of the hop, which consists of 36 resin, 12 wax, 11 bitter extract or *lupulin*, 5 tannin, 10 extractive insoluble in alcohol, and 46 insoluble residue. (See also Payen and Chevallier, *Jour de Phar.*, viii. 216.) Some of these bitters have been alluded to above.

Bryonin, obtained by Vauquelin and Brandes from the *Bryonia alba*: *cytisin*, from the *Cytisus laburnum*, by Chevallier and Lassaigne; *scillitin*, from the *Scilla maritima*, by Vogel; *senegin*, from the *Polygala senega*, by Gehlen; *sapo*

"Treat powdered gentian with cold ether, which in forty-eight hours furnishes a greenish-yellow tincture; this being filtered, poured into an open vessel, and exposed to heat, passes on cooling, (if the liquor be sufficiently concentrated,) into a yellow crystalline mass, with the odour and taste of gentian very powerfully developed. This mass is to be treated with alcohol, until it ceases to yield a citron-colour. The washings are then to be united and exposed to a strong heat, when the crystalline substance reappears and concretes towards the close of the evaporation into a mass which is exceedingly bitter. This, taken up again by weak alcohol, is dissolved, with the exception of a certain quantity of oily matter. The last spirituous solution, besides the bitter principle of gentian, contains an acid substance and the odorous matter also.

"By evaporating this liquid to dryness, washing the residue in water, adding a little calcined and well-washed magnesia, boiling, and evaporating in a water-bath, the greater part of the odorous matter of the gentian is dispersed, the acidity is removed by the magnesia, and the bitter principle remains partly free and partly combined with the magnesia, to which it imparts a fine yellow colour. On boiling this magnesia with ether, the greater part of the bitter principle is obtained, which may be isolated and rendered pure by evaporation. If it be desired to separate the greater part of the bitter principle that remains in the magnesia in a fixed state, and which could not be taken up by the ether, we may treat it with oxalic acid in sufficient quantity to produce slight acidity. The acid seizes upon the magnesia, and sets the bitter principle at liberty, which may be recovered in the manner already described.

"Gentianine is yellow, inodorous, possessing in a powerful degree the aromatic bitter taste of gentian, which is very much increased by solution in an acid. It is very soluble in ether and alcohol, and separates by spontaneous evaporation under the form of delicate crystalline needles of a yellow colour. It is much less soluble in cold water, which it renders notwithstanding very bitter; boiling water more readily dissolves it. Diluted alkalis heighten its colour very much, and dissolve a little more of it than water. Acids diminish its yellow colour in a very remarkable manner. With sulphuric and phosphoric acids the solution is almost colourless; but with the weaker acids, such as acetic, it is still yellowish. Concentrated sulphuric acid carbonizes it and destroys its bitterness. Exposed in a glass tube to the heat of boiling mercury, gentianine sublimes in the form of small yellow crystalline needles, and is partially decomposed. It has no sensible effect on turnsol, either when blue or reddened by acids. It is apparently neutral."

nin, from the *Saponaria officinalis*; *guaranin*, from the fruit of the *Paullinia sorbilis*, by Martius; *Columbin*, from *Calumba root*, are a few of the active principles of plants which have been regarded as distinct proximate components. Among the investigations of this kind, those relating to *sarsaparilla* seem to hold out promising results, for there are peculiarities belonging both to the chemical and medical properties of the root, which will probably be traced to a distinct substance. The *parillin* and *smilacin* of Pallotta and Folchi I have not been able to identify. The systems of Berzelius and Gmelin may be consulted for abstracts of what is known upon the above subjects.

13. Thein. According to Oudry, *tea-leaves* contain a peculiar principle, (salifiable base?) which he says may be separated as follows (Berzelius, *Lehrbuch*, iv.) 12 parts of tea were infused for twenty-four hours in 200 of cold water, in which three of common salt were dissolved. The infusion was evaporated to dryness, and the residue digested in alcohol of 0.81; the residue of this alcoholic tincture was then dissolved in water, and digested with magnesia, and filtered. On evaporating the filtered liquor to a certain degree of concentration, crystals of *thein* were obtained, and the magnesian residue, digested in alcohol, yielded a further portion.

Thein requires 30 to 40 parts of water at 50° for solution, and crystallizes irregularly on evaporation. When heated, it first fuses and is then decomposed. It has no alkaline properties to tests, but it forms crystallizable compounds with sulphuric and with citric acid. Berzelius observes that these statements require corroboration.

Some years ago I examined the varieties of tea in common use (*Quarterly Journal*, xii., 201), and found that the quantity of astringent matter precipitable by gelatine is somewhat greater in *green* than in *black tea*, though the excess is by no means so great as the comparative flavours of the two would lead one to expect. The entire quantity of soluble matter is also greater in *green* than in *black tea*, but the extractive matter not precipitable by gelatine is greater in the latter.

The following table shows the respective quantities of soluble matter in water and in alcohol, the weight of the precipitate by isinglass, and the proportion of inert woody fibre in green and black tea of various prices. It is given, not as throwing any important light upon the cause of the different qualities and effects of tea, but as containing the results of actual experiments. It will be remarked, that when tea-leaves have been exhausted by water repeatedly affused, alcohol is still capable of extracting a considerable quantity of soluble matter: the alcoholic extract, infused in boiling water, furnishes a liquid which smells and tastes strongly of tea, and which, were it not for the expense of the solvent, and the trouble attending its separation, might perhaps be profitably employed.

One hundred parts of Tea.			Soluble in Water.	Soluble in Alcohol.	Precipitate with Jelly.	Inert Residue.
Green Hyson .	14*s.*	per lb.	41	44	31	56
,,	12*s.*	,,	34	43	29	57
,,	10*s.*	,,	36	43	26	57
,,	8*s.*	,,	36	42	25	58
,,	7*s.*	,,	31	41	24	57
Black Souchong	12*s.*	,,	35	36	28	64
,,	10*s.*	,,	34	37	28	63
,,	8*s.*	,,	37	35	28	63
,,	7*s.*	,,	36	35	24	64
,,	6*s.*	,,	35	31	23	65

§ XX. PARTS OF PLANTS.

I SHALL include in this section a short notice of the chemical components of some of the *parts of plants* useful in medicine and the arts, and which I have not elsewhere noticed. The third volume of Berzelius' *Lehrbuch* (German or French translation), and the article on *Chemical Botany* in Leopold Gmelin's *Handbuch* (vol. iv.), may be referred to for further details.

1. ROOTS. *Allium sativum*, and *Allium cepa*. *Garlic* and *onions* have been but imperfectly examined. They both yield, on pressure, a juice strongly odorous, and which reddens on exposure to air, and is acid; they yield a volatile oil on distillation, and onions afford *mannite*. (p. 906.)

Amomum curcuma, or *Curcuma longa*. *Turmeric-root*, as a colouring-material, has been above noticed (p. 942). It contains, according to John, 1 yellow volatile oil, 12 resin like gamboge, 14 gum, 57 lignin. Turmeric is cultivated in the East Indies, and used as a condiment, especially in *Curry-powder*. Digested in water or alcohol, it furnishes a large proportion of yellow colouring-matter. Most of the acids render it paler, and the alkalis change it to a deep brick-red; hence its use as a test of the presence of alkaline matter. It is also reddened by boracic acid, and by muriatic acid gas. Some of the peculiarities of the colouring-principle of turmeric have been noticed by M. Desfosses (*Ann. de Chim. et Phys.*, xvi., 75), and by Mr. Faraday (*Quar. Jour.*, xi., 403).

Amomum zinziber. (Bucholz.) Ginger-root contains 1.56 volatile oil, 3.6 acrid resin, 10.5 acrid and sourish extractive, 12.5 gum, 19.75 starch? 8.3 mucilage, 26 extractive, 8 lignin, remainder water and loss.

Angelica archangelica. Essential oil and fragrant aromatic resin 6.7, bitter extract 12.5, gum 33.5, inulin 4, matter soluble in alkali 7.3, lignin 30, water and loss 6. (John.)

Anthemis pyrethrum. The stimulating power of this root upon the salivary glands is due to its soft resin. It contains traces of volatile oil, soft resin 5, yellow extractive 14, gum 11, inulin 33, lignin 35. (Gautier.)

Aristolochia serpentaria. Volatile oil 0.5, yellow soft resin 2.85, extractive 1.70, saponaceous gum 18.10, lignin 62.4, water and loss 14.5. (Bucholz.)

Asarum europæum. In the root Lassaigne and Feneulle found a crystallizable volatile oil, somewhat resembling camphor. It has been called *asarin*.

Aspidium filix mas. Male fern-root contains, according to Morin, a trace of volatile oil, fat oil, sugar, starch, tannin, pectine, malic and gallic acids combined with lime and potassa, phosphate of lime, and lignin; its ashes yielded silica, alumina, and oxide of iron.

Berberis vulgaris. The root yielded 2.55 of brown colouring-matter, precipitable by acetate of lead; 6.62 of a fine yellow extract (*dye-stuff*), not so thrown down; gum 0.35, starch 0.2, oil 0.4, soft resin 0.55, lignin 55.4, water, earthy and alkaline salts, &c., 35.

Beta vulgaris. *Common beet-root*. (See pp. 905, 922).

Brassica rapa. Turnips. (See pp. 896, 922.)

Bryonia alba. Bryonin has been above adverted to. According to Brandes and Firnhaber the root contains, bryonin and a little sugar 1.9, resin and a little wax 3.4, mucilage, gum, starch, and pectine 29.4, albumen 6.5, extractive 1.7, lignin 15.25, water 20.

Calicocca, or *Cephaelis ipecacuanha. Pyscotria emetica.* Ipecacuanha-root has been examined by MM. Pelletier and Majendie, and an account of their researches is published by M. Robiquet, in the *Ann. de Chim. et Phys.*, iv., 172. 100 parts of this root, deprived of the woody fibre which traverses its centre, afforded, fatty matter 2, emetina 14, gum 16, starch 18, woody fibre 48, a trace of wax, loss 2. The means of separating the *emetic principle* have already been described. (See p. 1040.)

Cichorium intibus. Succory-root is much used in Germany and elsewhere, when roasted, as a substitute for coffee: it has not been satisfactorily analyzed. According to Juch it contains 0.25 bitter extractive, 0.03 resin, traces of sugar, and the rest lignin.

Cochlearia armoracia. Horseradish. Einhof obtained from 4 pounds of the fresh root, 3 lbs. 2 oz. water, 20 grains volatile oil, 31.5 grs. albumen, 1.5 oz. and 20 grs. of starch, 1.5 oz. of gum and sugar, 6 grains bitter resin, 1 drachm 41 grs. acetate of lime, sulphate of lime, and acetic acid, 8 oz. lignin.

Colchicum autumnale. (See *Veratria*, p. 1035.) The bulbs contain a fatty matter resembling that of veratria, and of sabadilla seed? also gum, inulin, starch, extractive, gallate of veratria, and lignin. 100 lbs. of the recent bulbs yield between 18 and 19 lbs. of *pharmaceutical extract.*

Columbo. The supposed existence of a distinct principle in this root, has been adverted to; it contains, according to Planche, one-third its weight of starch, and a peculiar nitrogenous principle, to which the tendency of its infusion to putrefy is ascribed; also a peculiar yellow bitter, not thrown down by metallic salts, and soluble in water and alcohol, to which its medical virtues are due: one-third its weight is lignin. The average produce of *pharmaceutical extract of columbo* is 62 *per cent.*

Convolvulus jalappa. Jalap, analyzed by Cadet de Gassicourt, yielded 10 resin, 5 starch and albumen, 44 gummy extract, 28 lignin, exclusive of salts, water, and loss. The supposed existence of *jalapin* has, I believe, not been verified. The average produce of *pharmaceutical extract of jalap* (*Lond. Phar.*) is 66 *per cent.*

Crameria triandra. Rhatany root. 38.3 tannin, 6.7 sweet extractive, 2.5 azotised mucilage, 8.3 starch, 43.3 lignin.

Daucus carota. Carrots have been mentioned as a source of sugar and pectine (pp. 864, 922.) Hermbstadt obtained 6½ lbs. of syrup from 124 lbs. of carrots.

Gentiana lutea. (See p. 1046.) According to Henry (*Ann. of Phil.*, xvi., 98), gentian contains the following substances: 1. a substance resembling bird-lime; 2. a resin combined with oil, which gives to gentian its peculiar odour; 3. a bitter extractive principle; 4. gum and colouring-matter; 5. phosphate of lime? 100 lbs. of gentian-root yield about 62 of pharmaceutical extract.

Glycyrrhiza glabra. Two of the compounds of *liquorice-root* have already been mentioned, namely, a peculiar *sugar*, and *asparagin*, (pp. 997, 1042.) Robiquet found in it the following substances (*Ann. de Chim.*, lxx.): 1. starch; 2. gluten; 3. liquorice-sugar; 4. phosphate and malate of lime and magnesia; 5. an acrid oil; 6. a crystallizable substance resembling asparagin; 7. woody fibre.

Inula helenium. (See *Inulin*, p. 914.) Elecampane-root contains, volatile oil 0.4, wax 0.6, acrid soft resin 1.7, bitter extractive soluble in alcohol and water 36.7, gum 4.5, inulin 36.7, albuminous matter 13.9, lignin 5.5. (John.)

Leontodon taraxacum. Dandelion-root is stated by John to contain in its milky juice, a portion of caoutchouc, besides sugar and gum, and a very small quantity of bitter extractive. 100 lbs. of the fresh root yield 11 lbs. of *pharmaceutical extract.*

Marantha arundinacea. The root of this plant has been mentioned as a source of the species of starch which we call *arrow-root.* The fresh root contains, according to Benzon, volatile oil 0.7, starch 26, albumen 1.58, gummy extract 0.6, lignin 6, water 65.6.

Orchis mascula. The root, called *salep*, contains *starch* and *mucilage.*

Pastinaca sativa. From 124 lbs. of parsneps Hermbstadt obtained 5½ lbs of syrup: according to Drapier they yield 12 *per cent.* of sugar.

Polygala senega. Senega-root yields 7.5 soft resin, 6.15 *senegin*, 26.85 extractive, 9.5 gum and albumen, 46 lignin.

Rheum palmatum. (See p. 1046.) 100 lbs. of Indian rhubarb yielded 69 lbs. of aqueous extract.

Rubia tinctorum. *Madder-root* is an article of great importance in *dyeing;* it grows wild in most parts of the south of Europe, and is largely cultivated in some parts of Holland and the Levant; its red colour is apt to be injured by drying, a process requiring much caution. Good madder has a strong and peculiar smell; it exhibits, when cut, a cortical, and a woody part of a red colour, intermixed in the former with yellow spots. The red portion is most soluble. A peculiar substance, obtained from madder, has already been noticed under the name of *Alyzarine.* (See p. 936.)

Scorzonera hispanica. The fresh root of this plant contains, 9 starch, 3 resin, 10 extractive, 32 water, 46 lignin. (Juch.)

Smilax sarsaparilla. The varieties and uses of this root I have described in the *Manual of Pharmacy.* See also p. 1047, *note.* Cannobio's analysis is as follows: acrid bitter resin 2.8, gummy extract 5.5, starch 54.2, lignin 27.8, loss 9.7. The relative quantity of starch compared with that of extractive is enormously great in some species as compared with others. The average produce of the *red sarsaparilla* in *pharmaceutical extract* is 33 *per cent.*

Solanum tuberosum. The analyses of *potatoes* have been given elsewhere. (See p. 908, *note.*)

Triticum repens. The root of this species of grass abounds in sugar; 100 parts of dry root (= 112 fresh) yield 17 to 18 parts of an agreeable syrup, (*Mellago graminis* of foreign pharmacy.) Pfaff has rendered it probable that it contains *manna-sugar.*

Valeriana officinalis. The *acid* of this root has been above described. It contains, according to Trommsdorff, volatile oil 1.2, a peculiar extractive, including the acid? 12.5, gum 18.75, an odorous soft resin 6.25.

The essential oil is the seat of the odour. 100 lbs. of clean valerian root yield between 38 and 39 of *pharmaceutical extract.*

Veratrum album. See *veratria* (p. 1035.) The root contains a peculiar fatty-matter, yellow extract, gallate of veratria, gum, starch, and lignin.

2. Barks. *Æsculus hippocastanum.* The bark of the *horse-chestnut* has been partially examined by M. Henry. (*Ann. de Chim.*, lxxvii.) It appears to contain scarcely any resin; water and diluted alcohol dissolve nearly the whole of its soluble contents, which are chiefly extractive and mucilage. Tincture of galls does not render its infusion turbid; it does not contain an alkaloid. According to Pelletier and Caventou, this bark contains a green fixed oil, a red resin, a red extract, a yellow-bitter extract, tannin, gum, and a free acid. (See *esculic acid*, p. 966, *note.*)

Brucia antidysenterica. The bark of this tree is in fact *angustura bark* (Bonplandia trifoliata), and not the *spurious angustura*, which is the bark of a strychnos. (See p. 1032.) Angustura bark (*cusparia* bark of our pharmacopœia), contains, according to Fischer, acrid volatile oil 0.3, bitter hard resin 1.7, balsamic soft resin 1.9, bitter extractive, with a trace of caoutchouc, 3.7, gum 5.7, lignin 89.1.

Cinchona lancifolia, *cordifolia*, and *oblongifolia*, and other species. (See *cinchonia*, *quinia*, &c.) The varieties of Peruvian bark have been examined by MM. Pelletier and Caventou. In the *cinchona lancifolia*, or *pale bark*, they found the following constituent parts: 1. Cinchonia, combined with kinic acid; 2. green fatty matter; 3. red and yellow colouring-matter; 5. tannin; 5. kinate of lime; 6. gum; 7. starch; 8. lignin.

In *yellow bark* they found, 1. quinia, with kinic acid; 2. yellow fatty matter; 3. yellow colouring-matter; 4. tannin; 5. kinate of lime; 6. starch; 7. lignin. In *red bark* the same substances as in the 2 former. There can be no doubt that the tannin, and probably the colouring extractives, as well as the alkaloids and the kinic acid, all contribute to the medical efficacy of these barks. The produce, in *pharmaceutical extract*, of *pale bark*, is about 36 *per cent.*

Croton cascarilla. This bark, analyzed by Trommsdorf, gave 1.6 volatile oil, 15.5 bitter soft resin, 18.7 bitter gummy extractive, 65.6 lignin. 100 lbs. of cascarilla bark yield about 30 of *pharmaceutical extract.*

Daphne Mezereon. Gmelin and Bär obtained from *mezereon-bark*, daphnin (p. 1043), wax, acrid resin, yellow colouring-matter, a saccharine and brown extract, gum, malic acid, lignin, and several salts. (See Berzelius, for details.)

Laurus Cassia. The bark contains volatile oil 0.8, tasteless pale-brown roft resin 4, gummy extract 14.6, lignin 64.3, water and loss 16.3. (Bucholz.)

Laurus Cinnamomum. The finest Ceylon cinnamon-bark yields essential oil, a soft aromatic resin soluble in ether, tannin, extractive, gum, and above 80 *per cent.* of lignin. (Vauquelin.)

Pinus silvestris. The inner bark of the young Scotch fir was, for many years, used by Westring in the cure of intermittents. Berzelius found in it soft resin 6.9, tannin with extractive 6.65, a bitter extractive, precipitable by subacetate of lead, and containing sugar, 15.0, cinchonate of lime 0.53, a gelatinizing principle 18.15, water and loss 5.25. Berzelius considers the gelatinizing-matter to be pectic acid and starch; and hence the nutritive property of this bark, which induces the peasantry in northern countries to use it as a substitute for bread in years of scarcity. (See p. 920.) The soft resin is turpentine?

Quassia simarouba. The bark, used in medicine, contains a volatile oil, bitter extract, traces of gallic acid, and many salts.

Quercus robur. Oak-bark. (See p. 926.) 100 lbs. of oak-bark yield, on an average, 20 lbs. of aqueous extract.

Ulmus campestris. Elm-bark contains a green fatty matter, soluble in alcohol and ether; it is obtained by the action of water upon the alcoholic extract of elm-bark, which leaves it soluble in ether. This bark also contains a peculiar gelatinous matter (a salt of pectine?) A peculiar and modified extractive oozes from elm-bark, which I have above described under the name of *ulmin.* Berzelius justly inveighs against the application of that term to a variety of dissimilar products.

Wintera aromatica or *Winter aniacanella; Winter's canella-bark:* it contains an acrid volatile oil, mild resin, coloured extractive, a peculiar kind of extractive and of sugar, gum, starch, albumen, lignin, and several salts. (Henry, Petroz, and Robinet.)

Zanthoxylum caribæum. (*Z. clava Herculis.*) The bark of this tree is used in the Antilles as a febrifuge; Chevallier and Pelletier found in it a peculiar principle, which they termed *zanthopicrite.* It is soluble in water, very soluble in alcohol, insoluble in ether; it forms yellow silky crystals, and is very bitter and astringent; it has no alkaline reaction; animal charcoal abstracts it from its aqueous solution, and hot alcohol extracts it again from the charcoal. (*Jour. de Chim. Med.*, ii., 314.)

3. WOODS. *Cæsalpinia crista. Fernambuc* or *Brazil-wood. Peach-wood?* (See p. 937.) This tree grows in Brazil, in the Isle of France, Japan, and other countries: the wood is hard and heavy, and, though pale when recent, it acquires a deep-red colour by exposure. Digested in water, it affords a fine red infusion, of a sweetish flavour: the residue, which appears nearly black, imparts much of colour to alkaline liquors. With alcohol, it gives a deep-red tincture; alkalis and soap convert its red colour to a fine purple: hence paper, tinged with Brazil-wood, is sometimes used as a test for alkalis; acids render it yellow; alum produces a fine crimson lake with infusion of Brazil-wood; chloride of tin forms with it a crimson precipitate, bordering on purple; the salts of iron give a dingy purple colour. Sulphuretted hydrogen destroys the colour of infusion of Brazil-wood, but it re-appears on expelling the gas. (Chevreul, *Annales de Chimie*, lxvi.)

Guaiacum officinale. Lignum-vitæ. Hagen obtained 3 *per cent.* of *resin of guaiacum* (p. 977, *note*) from this wood. From 1 ounce of rasped wood Trommsdorf obtained (in different samples) from 35 to 160 grains of matter soluble in alcohol, and from 45 to 96 grains of watery extract. When guaiacum-wood is boiled in water a small part of the resin is dissolved; the residue becomes blue by exposure to air. (*Phil. Trans*, 1811.)

Hæmatoxylon campechianum. Logwood. (See *dye-stuffs*, p. 937.) This wood imparts a fine purple or crimson colour to pure water, but its tint is altered by the slightest metallic impregnation; alkalis deepen it, and acids render it paler; alum forms with it a violet-coloured lake; sulphate of iron renders the infusion of logwood deep purple, or nearly black; sulphate of copper and acetate of lead throw down brown and purple precipitates; and muriate of tin precipitates the whole of the colouring-matter in the form of a purple compound. Many of the colours which logwood produces are not very durable. (Bancroft, on *Permanent Colours*, ii., 338. Chevreul, *Annales de Chimie*, lxvi., 254.) 100 lbs. of logwood yield 25 lbs. of *pharmaceutical extract.*

Morus tinctoria. (See p. 941.)

Pterocarpus santalinus. This tree, which affords *saunders* or *red sandal-wood*, is a native of several parts of India. Its deep-red colouring-matter is insoluble in water, but readily soluble in alcohol; it is chiefly employed for colouring a few pharmaceutical tinctures. The insolubility of its colouring-principle in water, furnishes a ready mode of distinguishing between it and *Brazil-wood;* and its solubility in alcohol renders it probable that it is of a resinous nature. (See p. 938.)

Quassia excelsa. The wood of this tree, which has long been used in medicine as a powerful bitter, has not been minutely examined; it is said to contain a slight trace of volatile oil, a peculiar bitter extractive (*quassin*), gum, lignin, and salts. The bitter extractive is much more soluble in common alcohol than in water. It is precipitated, according to Pfaff, by acetate of lead: its aqueous solution, sweetened, is a good *fly-poison.*

Solanum dulcamara. The stalks of this plant contain, according to Pfaff (*Mat. Med.*), 21 *per cent.* of a saccharo-bitter extract, which he terms *Picroglycion.* Its bitterness is derived from *malate of solania.* (p. 1037.)

Strychnos columbina. Snakewood. It contains green fat, yellow extractive, gum, strychnate or igasurate of strychnia (p. 1032), and lignin.

4. HERBS, FUNGI, LICHENS, &c. *Anemone pulsatilla* and *nemorosa.* The concentrated distilled water of this plant, when kept for some weeks in a cool place, deposits a crystalline matter, originally described by Heyer, and afterwards by Vauquelin and Robert. (*Jour. de Phar.*, vi., 229.) It passes over with the vapour of water, and appears at first as an oil, which afterwards concretes. Its vapour is acrid, and the substance itself poisonous. It burns like camphor, is very sparingly soluble in water, and decomposed by concentrated acids and alkalis. It has been termed *anemonin*, and *anemone camphor.*

Many other plants, especially many species of *ranunculus*, *clematis*, and *rhus*, and the *arum maculatum*, and *polygonum hydropiper*, contain an acrid principle analogous to, and by some considered identical with, the above.

Artemisia absynthium. Wormwood has not been examined by modern chemists. According to Dörffurt, dry wormwood yields about 1 *per cent.* of volatile oil, 8.5 to 9 of green resin, 25 to 30 of gummy extract, which, when burned, leaves 11.5 *per cent.* of the original weight of the dried herb, of ashes, two-thirds of which are carbonate of potassa: hence the term *salt of wormwood* applied to that salt. According to Kunsemüller, the potassa in the herb is in a state of *acetate*.

Agaricus, &c. See Braconnot's researches, already quoted, (*Fungic and boletic acid, sugar, fungin.*) The substances found in all *fungi* are a crystalline and a butyraceous fat, albumen, sugar, two azotised bodies, one of which is only soluble in water, and the other in water and alcohol, and salts of potassa and of ammonia, with fungic, boletic, phosphoric, and sometimes acetic acid, fungin (a form of lignin) and water. Many contain gum and mucilage.

When bruised fungi are digested in water, they yield an *extract*, from which alcohol abstracts sugar and an azotised substance, separable by a little alcohol, which dissolves the former and leaves the latter. This azotised substance yields a brown solution with water, which, when evaporated, leaves it in the form of a brown extract, smelling, when heated, like roasted meat, evolving ammonia when distilled, and in all respects resembling the animal extractive called *osmazome*. The portion of the extract, insoluble in alcohol, dissolves in water, with the exception of a little albumen. It also dissolves in dilute alcohol: it does not gelatinize, and when destructively distilled, yields carbonate of ammonia.

The insoluble portion of the fungi, which remains after digestion in water, digested in alcohol, yields stearin and elain, and a little resin.

Chemical analysis has not thrown any light upon the *poisonous* nature of certain mushrooms.

Asparagus officinalis. The juice of *asparagus*, in the state in which it comes to table, yields, as already stated (p. 1042), a very curious product, which has been termed *asparagin*, it also contains a little albumen, wax, and resin. The residue of the asparagus, which contains its eatable part, for boiling probably abstracts the matters contained in its expressed juice, has not been examined; nor have we any accurate information as to the cause of the singular odour which it imparts to the urine: it has been said, however, that *asparagin* is diuretic, and gives the urine the same odour.

Boletus juglandis, *laricis*, and *pseudo igniarius*, have been examined by Braconnot. (*Ann. de Chim.*, lxxx., 273.)

Brassica oleracea. Cabbage. The fresh leaves yield, *per cent.* 0.63 green fecula, 0.29 albumen, 0.05 resin, 2.89 gum, or mucilaginous extract, 2.84 extract soluble both in alcohol and water. The saline matters are sulphate and nitrate of potassa, chloride of potassium, malate and phosphate of lime, phosphate of magnesia, and oxides of iron and manganese. (Schrader.) So that, according to this analysis, the cabbage may be assumed to contain about 7 *per cent.* of soluble matter, the remainder being lignin and water.

Cetraria islandica. Lichen islandicus. Iceland moss has been somewhat minutely examined by Berzelius; the details of his analysis are given in his *Lehrbuch.* The result is, green wax 1.6, yellow colouring extractive 7.0, bitter principle 3.0, sugar 3.6, gum 3.7, starch 44.6, starchy lignin 36.2. A trace of gallic acid, tartar, tartrate of lime, and phosphate of lime 1.9. It has also been analyzed by John, with the following results: green resin 1.5, extractive 10, inulin 8.0, modified inulin 40.0, insoluble parts 37.5, saline substances 3.0.

Cochlearia officinalis. The extract of the expressed juice contains brown sweet extract, soluble in hot alcohol, and precipitable by chlorine and by tannin 48.33: matter insoluble in alcohol, but precipitable by tannin 32.00, salts of potassa with vegetable acids 15.3. The fresh plant contains a sulphurous acrid oil, and sometimes nitre.

Conium maculatum. The juice from 100 parts of fresh *hemlock* yielded green fecula 0.80, albumen 0.31, resin 0.15, gum 3.52, extractive 2.73, (Schrader.) This much resembles the *cabbage*, and takes no account of the poisonous property of hemlock (see *Conia*, p. 1039.) 100 lbs. of fresh hemlock yield an average produce of 4 lbs. of *pharmaceutical extract.*

Helvella mitra. Morels contain, according to Schrader, stearin and elain 4.0, sugar 2.0, azotised extractive (*vegetable osmazome*) 29.4, gummy azotised extractive 5.4, albumen 1.2, boletate and phosphate of ammonia and potassa 8.0, fungin 39.6, water 10.4. It is evident that the peculiar flavour and characters of mushrooms, and similar articles of food, is referable to the extractive matter containing nitrogen, and hence resembling an animal product, which I have above termed *vegetable ozmazome:* this substance deserves further examination, especially by the culinary chemist.

Hordeum vulgare. (See the results of Einhof's experiments. p. 922.)

Hyoscyamus niger. Henbane requires to be minutely examined. (See *hyoscyamia*, p. 1037.) 100 lbs. of the herb yield, upon an average, 3 lbs. and a quarter of *pharmaceutical extract.*

Indigofera anil, and *Isatis tinctoria.* (See p. 943.)

Lichen islandicus. (See *Cetraria.*)

Melissa officinalis. Balm yields, according to Dehne, 1.1920th its weight of volatile oil. The infusion of balm (often drunk as *balm-tea*), contains tan, extractive, and gum. Alcohol extracts a little resin.

Pisum sativum. The components of *peas*, are stated at p. 922.

Rhus toxicodendron. The juice of the leaves of this species, and of the *Rhus radicans* and *vernix*, contains an acrid poison, the nature of which has not been accurately ascertained: it is also a substantive *black dye*, extremely permanent; cotton or linen imbued with it acquiring a deep black by exposure: the nature of this colouring-principle has not been examined, but it seems somewhat analogous to indigo.

5. Leaves. *Aconitum napellus.* The leaves of this and other species of *monkshood*, contain a very poisonous principle (alkaloid), which has already been alluded to. Its paralyzing power upon the organs of taste may be perceived by chewing a leaf of the plant, it produces a biting sensation upon the tongue, and *taste* is impaired for hours afterwards. Bucholz found in the fresh leaves 83.75 *per cent.* water: the residue, washed with water, left 15 *per cent.* of woody-fibre. On heating the expressed juice, a green and albuminous fecula subsided, amounting, with a little wax, to 5.0. Alcohol abstracts from the inspissated juice of aconite a brown extractive, of a bitter, sourish, saline, and acrid flavour. The part inso-

luble in alcohol yielded to water 3.75 of gum, and left 1.0 of malate and citrate of lime.

Arbutus uva ursi. The leaves of the *whortle-berry* are very rich in tannin, and might be much more employed than they are in tanning and dyeing: they might be abundantly imported from the north of Europe. At present they are only used in medicine as an astringent and tonic, especially affecting the urinary passages.

Atropa belladonna. (See *Atropia*, p. 1036.) 100 lbs. of the fresh herb yield about 2 lbs. 8 oz. of *pharmaceutical extract.*

Cassia senna. The existence of a purgative bitter extractive in these leaves has been above mentioned, (*Cathartin*, p. 1045.) See also Dr. Thomson's *London Dispensatory.* 100 lbs. of senna-leaves, yield 50 lbs. of *pharmaceutical extract.*

Centaurea benedicta. The dried herb yields volatile oil, chlorophyll and fat-oil, brown resin, extractive, bitter principle, sugar, gum, albumen, ligneous matter, and various salts. (Morin, *Journal de Chim. Med.*, iii., 105.)

Datura stramonium. The fresh leaves of the *thorn-apple* contain 0.64 green fecula, 0.15 albumen, 0.12 resin, 0.60 extractive, 0.58 gum, 0.23 difficultly-soluble salts, 5.15 lignin, 91.25 water. (Promnitz.) See *Daturia*, p. 1037.) 100 lbs. of the fresh herb afford an average produce of 2 lbs. 12 oz. of the *pharmaceutical extract.*

Digitalis purpurea. The leaves of the *foxglove* contain, according to Rein and Haase, a soft, viscid green resin, soluble in ether; alcohol and volatile oils 5.5, extractive 15.0, superoxalate of potassa 2.0, lignin 52.0, water 5.5, (loss 5.) The activity of digitalis resides, according to Haase, in the soft resin. (See *Digitalia*, p. 1039.)

Menyanthes trifoliata. From 100 parts of the fresh leaves, Trommsdorff obtained 15.6 lignin: the green expressed juice deposits, on boiling, 0.49 fecula, from which alcohol and ether abstract 0.12 soft green resin, and 0.37 albumen remains. The filtered juice yields 3.92 of extract, containing gum, inulin, and extractive; the extractive includes a peculiar bitter principle, *menyanthin*, and an azotised substance.

Nicotiana tabacum. (See *Nicotina*, p. 1038.)

Salvia officinalis. 100 parts of fresh *sage-leaves*, yield extractive (including an azotised substance and nitrate of potassa), 2.12, gum 1.51, green resin 2.9, albumen 0.43, lignin 15.87, water and loss 77.17. They also yield 0.16 *per cent.* of a pale-yellow volatile oil; sp. gr. 0.864; soluble in alcohol, but difficultly so in ether. (Ilisch.)

Thea bohea and *viridis.* (See *Thein*, p. 1048.)

6. FLOWERS. *Anthemis nobilis.* *Chamomile flowers* yield, on distillation, a blue or green essential oil, which becomes yellow when kept. 100 lbs. of the dried flowers yield, upon an average, 2 lbs. 12 ozs. of oil, and 3 lbs. 4 ozs. of *pharmaceutical extract.*

Arnica montana. These flowers contain an acrid resin, to which their medicinal virtues are ascribed: they also yield a volatile oil, and much tannin, with some gallic acid.

Artemisia santonica. The buds of this plant are used as a vermifuge, under the name of *Semina cinæ.* Their active principle appears to be an acrid volatile oil.

Calendula officinalis. The *marigold petals* contain yellow-green soft resin 3.44, bitter extractive 19.13, gum 1.5, starch 1.25, mucilage (*Calendulin*, p. 896) 3.50, albumen 0.62, free malic acid with bitter extractive 6.84, malate of potassa 5.45, malate of lime 1.47, chloride of potassium 0.66, lignin 62.5. (This gives an excess = 7.33.) The leaves contain the same substances, and a little nitrate of potassa. (Geiger.)

Caryophillus aromaticus. Eugenia caryophillata. Cloves are the calyces and buds of this plant. They contain, volatile oil 18.0, tannin 13, extractive 4.0, tasteless resin 6.0, gum 13, lignin 28, moisture 18. (Trommsdorf.) By repeated distillation, Ostermeyer obtained 21.5 essential oil; he also obtained the oil of cloves, by *expression;* it then contained a peculiar kind of wax. The average produce of essential oil, as obtained from repeated experiments at Apothecaries' Hall, does not exceed 16 *per cent.* (See *oil of cloves*, p. 971.)

Crocus sativus. From 100 parts of fine *saffron*, Bouillon, Lagrange, and Vogel, obtained yellow volatile oil, with fat, 7.5, wax 0.5, polychroit (p. 942) 65, gum 6.5, albumen 0.5, lignin 10, water 10. Saffron, as it occurs in trade, is often very damp, and mixed with 5 or 6 *per cent.* of sand.

Rosa gallica. Red-rose leaves contain, according to Cartier, a red colouring-principle greened by alkalis, gallic acid, tannin, and albumen. From rose-leaves which have been infused in water, alcohol abstracts a yellow fixed, and a volatile oil. Dried rose-petals, digested in ether, yield oil, gallic acid, tan, and colouring-matter. When burned, their ash contains phosphate of potassa and lime (a vegetable salt of lime), chloride of potassium, silica, and oxide of iron.

Sambucus nigra. Elder-flowers have not been minutely examined; they contain a peculiar bitter extractive, and yield, on distillation, a buttery oil, which gives flavour to *elder-flower water.*

Tilia europæa. The flowers of the *lime-tree* contain, according to Pfaff, a peculiar odorous principle, which passes over in distillation with water, but cannot be separated in the form of volatile oil; but Brossat, from very large quantities of the flowers, obtained a little highly fragrant oil, lighter than water: they also contain tannin, sugar, gum, and lignin. They are well known to attract swarms of bees. When chewed, they appear very mucilaginous. Roux obtained from them, by the action of alcohol, a yellow colouring-matter.

7. FRUITS AND SEEDS. *Amomum repens. Cardamom seeds* yield 4 *per cent.* of volatile oil, and 12.5 of resin: the residue consists of mucilage and lignin.

Amygdalus communis. Sweet almonds contain 54 oil, 6 sugar, 3 gum, 24 albumen, 24 insoluble ligneous matter, 5 skins, 3.5 water, a trace of acetic acid and loss 0.5. (Boullay.) *Bitter almonds* contain the same principles, and the peculiar matters described at p. 971. The bitter almond-cake which remains, after the expression of the fixed oil, yields an average produce of 9 ozs. of volatile oil from the hundredweight, but, much depends upon the mode of distillation.

Cannabis sativa. *Hempseed* contains, according to Bucholz, 19.1 *per cent.* of oil: the residuary cake contains 24.7 *per cent.* of albumen, 43.3 of lignin and other insoluble matters; gum, sugar, and a trace of bitter extractive, constitute the residue.

Capsicum annuum. Bucholz found in the pods of *capsicum*, 7.6 wax, 4 acrid resin, 8.6 bitter aromatic extract, 21. gum and extractive, 9.2 gum, 3.2 albumen, 28 lignin, 12 water, loss 6.4 Braconnot terms the acrid soft-resin, which appears to constitute the active principle of this pepper, *capsicin*; it fuses when heated, and a single grain vaporized in an ordinary-sized room, is so diffused through the air as to cause it to excite coughing and sneezing.

Cassia fistula. The pulp of the seed-pods of an American and of an African variety of this tree, yielded Henry, i., sugar 69.25, gum 2.6, tannin 3.9, moisture 24.25; ii. sugar 61.0, gum 6.75, tannin 13.25, water 19.0. This pulp is medicinally used as a purgative.

Citrus aurantium and *medica.* Neither *oranges*, nor *lemons*, have been subjected to any accurate examination. Dried orange-peel yields from 16 to 20 *per cent.* of an agreeable and apparently peculiar bitter extract. Lemon-juice contains, according to Proust, 97.51 water, 1.77 citric acid, with bitter extract, gum, and a trace of malic acid, amounting together to 0.72 *per cent.*

Coffea arabica. See Caffein. (p. 1043.)

Croton tiglium. See p. 955.

Cucumis colocynthis. According to Meissner, the pith freed from seeds contains fat oil 4.2, a yellow, brittle, very bitter, resin, insoluble in ether, 13.2, colocyntin, (p. 1045,) 14.4, gelatinous matter 3.0, gummy extractive 17.6, lignin 19: the remainder being water and salts.

Cucumis sativus. *Cucumbers* have been examined by John, who found in the peeled cucumber, green colouring-matter 0.04, sugar, with extractive, 1.66, soluble albumen 0.13, fibres, softened by boiling and containing traces of phosphate of lime, 0.53, mucilage, free phosphoric acid, salts of ammonia, potassa, lime, and iron, with malic, phosphoric, sulphuric, and muriatic acids 0.5. Water 97.14. The peel of the cucumber contained the same substances, but only 85 *per cent.* of water, and the fibre resembled fungin.

Cytisus laburnum. See *Cytisin.* (p. 1046, *note.*)

Delphinium staphisagria. Brandes found in *staves-acre seeds*, stearin 1.4, oil 19.1, gum 3.15, starch 2.40, an azotised extractive, insoluble in alcohol, precipitable by acetate of lead and by infusion of galls, with traces of various salts 30.67, *delphia* 8.10, (see p. 1039,) albumen 4.12, sulphates and phosphates of potassa, lime, and magnesia, 5, water 10.

Fragaria vesca. Strawberries have never been anaylsed. Dried in *vacuo*, over sulphuric acid, they lose about 90 *per cent.* According to Scheele, the acid which they contain consists of equal parts of malic and tartaric acids. Their fragrancy passes over in distillation with water.

Humulus lupulus. See *Lupulin*, (p. 1046, *note.*) *Hops* yield about 27 *per cent.* of *pharmaceutical extract.*

Hyoscyamus niger. *Henbane-seed* contains, according to Brandes, 24.2 oil, 1.4 stearin, a trace of sugar, 1.2 gum, 2.4 mucilage, 1.5 starch, 3.4 extractive, 4.5 albumen, 26. lignin, 24. water: various salts, and a trace of *copper?* They are said to contain no narcotic principle.

Juglans regia. The outer green husk of the unripe *walnut* contains resinous green matter, tannin, extractive, starch, citric and malic acid, oxalate and phosphate of lime, lignin; and in the ash, potassa, and oxide of iron. The expressed juice is at first colourless, but becomes brown by exposure: it forms a good dye-stuff.

Juniperus communis. *Juniper-berries* contain a volatile oil and sugar; the former is most abundant in the berries just at their period of ripening; when they are quite ripe and black, it has chiefly passed into resin. The sugar is most plentiful in the deep blue berries, and is partly decomposed when they blacken and dry. Trommsdorff found in the *ripe* berries, volatile oil (sp. gr. 0.853) 1.0, brittle wax, soluble in hot alcohol, ether, and caustic potassa, 4.0, tasteless and inodorous resin 10.0, a peculiar kind of sugar 33.8, gum 7.0, lignin 35.0. The produce of essential oil, from the *German* berries, as ascertained by repeated distillations at Apothecaries' Hall, amounts upon an average to from 9 to 10 ounces from the 100 lbs., and from the *Italian* berries to 7 ounces.

Laurus nobilis. *Laurel-berries* have been examined by Bonastre: he found volatile oil 0.8, a crystallizable substance, which he calls *laurin,* 0.5, grease and fat oil 9.9, soft resin 0.8, starch 12.95, gum 8.6, mucilage 3.2, sugar 0.2, lignin 9.4, water 3.2. They also contain a free acid.

Menispermum cocculus. See *Picrotoxia*, (p. 1038.)

Momordica elaterium. (See *Elatin.*) Of the pharmaceutical product, termed *elaterium*, about 1 lb. 8 oz. is obtained from 100 bushels of the gourds.

Myristica moschata. *Nutmegs* contain, according to Bonastre, fat oil, (p. 957,) 31.6, volatile oil 6.0, starch 2.4, gum 1.2, free acid 0.8, lignin 54, (loss 4.) The usual produce in *volatile oil*, in the distillations at Apothecaries' Hall, is 4.5 *per cent.*

Myrtus pimenta. *Allspice* has been examined by Bonastre; he analysed the outer shell and the kernel, with the following results:—

	Husks.	Kernels.
Volatile oil	10.0	5.0
Green soft resin	8.0	2.5
Concrete fixed oil	0.9	3.2
Tannin and extractive	11 4	39.8
Gum	3.0	7.2
Brown gelatinous matter	4.0	3.8
Resinous substance	1.2	1.2
Saccharine extract	3.0	8.0
Malic and gallic acids	0.6	1.6
Lignin	50.0	16.0
Saline ash	2.8	1.9
Moisture	3.5	3.0
Loss	2.2	8.8

Oryza sativa. *Carolina rice* contains, fixed oil 0.13, sugar 0.29, gum 0.71, starch 85.07, gluten 3.60, lignin 4.8, water 5. *Piedmontese rice* contains, fixed oil 0.25, sugar 0.05, gum 0.10, starch 83.8, gluten 3.6, lignin 4.8, water 7. (Braconnot.)

Piper cubeba. *Cubebs* yield, on distillation with water, about 10.5 *per cent.* of volatile oil.

Piper nigrum. The acrimony of *black pepper* resides in a soft resin or balsam, and in volatile oil. See also *Piperin*, p. 1041.

Pisum sativum. *Peas.* See p. 922.

Prunus cerasus, &c. The analysis of cherries, plums, peaches, and apricots, is given at p. 877.

Pyrus communis and *malus.* *Pears* and *apples* have been examined by Berard, but there are many interesting points respecting them which remain unnoticed, such especially as the rapid change which some of them undergo by the action of oxygen, when they are cut and exposed to air, and during which, sugar appears to be formed; he also does not notice pectin or pectic acid, though perhaps it may be formed, as in *apple jelly*, by the action of heat upon their finely-divided lignin; he also overlooks tannin or gallic acid contained in many of those fruits, rendered evident by the blackening of the knives with which they are peeled. The following are the results which he obtained from *Beurré pears*, examined in three states, namely, i. ripe and fresh; ii. kept till mellow; iii. kept till brown or beginning to rot, and having lost 23.15 *per cent.* of water, &c.

	I.	II.	III.
Resinous green colouring-matter	0.08	0.01	0.04
Sugar	6.45	11.52	8.77
Gum	3.17	2.07	2.62
Lignin	3.80	2.19	1.85
Albumen	0.08	0.21	0.23
Malic acid	0.11	0.08	0.61
Lime	0.03	0.04	trace
Water	86.28	83.88	62.72

Apples contain the same ingredients as pears, but in somewhat different proportions, but the cause of *flavour*, and the *aroma* of these fruits, depends upon some volatile principle probably, which analysis has not detected.

Punica granatum. The *rind* of the *pomegranate* is used medicinally as an astringent: it contains, tannin 27.8, resin 0.9, extractive 32.8, gum 34.2, loss 5.1. (Reuss.) No lignin is here mentioned, so that the above are probably the soluble constituents only.

Ribes grossularia. *Gooseberries* have been analyzed by Berard, with the following results.

	Unripe.	Ripe.
Resinous green colouring-matter	0.03	——
Sugar	0.52	6.24
Gum	1.36	0.78
Albumen	1.07	0.86
Malic acid	1.80	2.41
Citric acid	0.12	0.31
Lime	0.24	0.29
Lignin, including the seeds	8.45	8.01
Water	86.41	81.10

Ricinus communis. This seed, which affords *castor oil* (p. 954), has been analysed by Geiger: it yielded 69.09 kernel, and 23.82 husk: this quantity of husk or shell yielded, resin and bitter extract 1.91, gum 1.91, lignin 20.0. The kernel (69.09 parts) afforded, fixed oil 46.19, gum 2.40, albumen 0.5, starch with lignin 20, water 7.09.

Secale cereale. The analysis of *rye* is given above, p. 922.

Secale cornutum. The *ergot of rye*, which appears to possess such extraordinary influence in promoting the natural contractions of the uterus in child-birth, has been analysed by Vauquelin and by Pettenkofer, but their researches throw no light upon its medical virtues. It yields a deep brown tincture to dilute alcohol, which on evaporation leaves 18.72 *per cent.* of wax, which fuses at 212°. The tincture, deprived of wax, affords a transparent brown bitter and sour extractive, which becomes moist in the air; after some days small cubic crystals form in it, which Pettenkofer suspects to be a salt of morphia, but of this there is no evidence. Water takes up a brown bitter extractive from the residue of the ergot insoluble in alcohol. The extraordinary medicinal peculiarities of ergot render an accurate chemical examination of it extremely desirable.

Strychnos nux vomica, &c. See *Strychnia*, p. 1032.

Tamarindus indica. The pulp of this fruit contains, according to Vauquelin, 12.5 sugar, 4.7 gum, 6.2 jelly, 0.4 malic acid, 9.4 citric acid, 1.5 tartaric acid, 3.2 bitartrate of potassa, 36 ligneous matter, 30 water. Scheele asserts that the whole of the acid in tamarinds is the tartaric acid.

Triticum hibernum. The composition of *wheat* is given at p. 922.

Vitis vinifera. The juice of sour grapes only contains tartaric acid. The juice of the ripe grape contains odorous matter, sugar (p. 906), gum, albumen, a trace of malic acid and malate of lime, free tartaric acid, tartrate of lime, and bitartrate of potassa, (also racemic acid?)

Zea mais. According to Gorham, maize, or Indian wheat, contains starch 77, *zein* 3, albumen 2.5, sugar 1.45, extractive 0.80, gum 1.75, sulphate and phosphate of lime 1.5, lignin 3, water 9. According to Bizio, zein contains nitrogen as an ultimate element: Gorham regards it as a gluten without nitrogen.

§ XXI. PHENOMENA AND PRODUCTS OF VINOUS FERMENTATION. ALCOHOL.

The term *fermentation* is employed to signify the spontaneous changes which certain vegetable solutions undergo, placed under certain circumstances, and which terminate either in the production of an intoxicating liquor, or of vinegar; the former termination constituting *vinous*, the latter *acetous* fermentation.

The principal substance concerned in vinous fermentation is *sugar;* and no vegetable juice can be made to undergo the process, which does not, either originally contain it, or some other principle, such as starch or starch-gum, capable of being converted into sugar. In the production of *beer*, the sugar is derived from the *malt;* in that of *wine*, from the juice of the *grape.*

The change which *barley* suffers in the operation of *malting* has been already stated (p. 910), and in a number of other processes, starch passes through similar changes, first becoming *gum*, and then *sugar;* and to effect these changes it is only necessary that a portion of sugar should be present, which, when it begins to ferment, leads to the successive conversion of the remaining unchanged starch into sugar. Thus it is, that a small addition of malt to a large proportion of unmalted grain, forms a mixture, which, placed under the requisite conditions, tends to vinous fermentation; and that any variety of starch may be rendered applicable to the process, by the addition of any of the ordinary forms of sugar: among common vegetables applicable to this purpose, the *potato* stands pre-eminent, the cause of which will be obvious by reference to its analyses, given in the Table at p. 922.

But a solution of *pure* sugar is not *alone* susceptible of vinous fermentation, and although a mixture of common sugar, and especially of raw sugar and water, will often ferment sluggishly, this arises from what may be termed *impurities* in the sugar.

The substance which, of all others, tends in these cases to induce fermentation, is some form or other of *vegetable gluten* (p. 915), consequently of an *azotised* or nitrogeniferous substance, for other analogous compounds, and even *animal products*, may be resorted to. But before gluten is fit for this purpose, it must itself have undergone some change, for which the contact of oxygen is apparently required, and of all the forms of modified gluten applicable to the purpose, *yeast*, or, as it is sometimes termed, *ferment*, is the most so.

Yeast is the substance which collects, as a scum, and sediment, during the vinous fermentation of *wort*, and is derived from the albumino-glutinous parts of the grain: it is generally used in a moist state, but, for convenience, it is sometimes partially dried by pressure and exposure to a gentle heat; in its moist state it soon runs into putrefactive fermentation at common temperatures, absorbing oxygen, evolving carbonic acid, acquiring a fetid odour, and becoming sour from the formation of acetic acid. Subjected to destructive distillation it yields some ammoniacal products. Perfect desiccation, long exposure to a boiling heat, the action of alcohol, acids, and salts, render yeast ineffective. The nature of the action of the yeast upon the saccharine matter has not been accurately ascertained; but the changes which the latter undergoes during fermentation, have been satisfactorily explained: these we shall recur to, when the nature of *alcohol*, which is the ultimate result, has been examined.

Beer. In the manufacture of *beer*, the malt is ground and infused in the *mash-tun*, in rather more than its bulk of water, of the temperature of 160° or 180°. At a higher temperature the mixture would *set*, as it is termed; that is, it would become an intractable gelatinous mass, not easily dissolved in, or even diffused through, the mass of water. In the mash-tun the malt is *exhausted* by the successive applications of fresh portions of water, and by frequent agitation, which is either effected by paddles or by machinery-power. The nature of this process, and of the manner in which it is performed in our large breweries, can only be adverted to here; they must be visited, to form a just conception of the ingenuity of the machinery, and the enormous magnitude of the operations there conducted.

The mixed infusions, as they run from the mash-tun, are called *wort*; its principal contents are *saccharine-matter*, *starch*, *mucilage*, and a small quantity of *gluten*. The strength of the wort is adjusted by its *specific gravity*, which is usually found by an instrument not quite correctly called a *saccharometer*, since it is influenced by all the contents of the wort, and not by the sugar only. It is a brass instrument, resembling the common hydrometer, of the shape shown in the margin, and so adjusted in weight as to sink to the point marked 0°, in distilled water, at the temperature of 70°, and when immersed in a liquor of the same temperature, and of the specific gravity of 1.100, it is buoyed up to the mark 100, just above the bulb. The intermediate space is divided into 100 equal parts, and, consequently, will indicate intermediate degrees of specific gravity. This is the most useful form of the instrument, though not that in common use. Brewers employ complicated and often unmeaning terms to designate the strength of their worts, and speak of the proportion of *saccharine*, *per barrel*, &c. A reform in this department of their business, by the introduction of a new instrument, and of tables showing the quantity of solid matter in worts of given density, and expressed in reference to specific gravity only, would be desirable.

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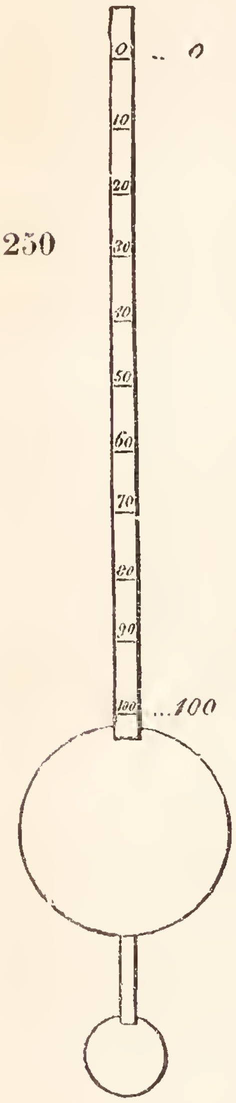

The specific gravity of the wort for ale is usually about 1.090 to 1.100, and for table-beer from 1.020 to 1.030. Those who are curious in the history of *ale* and *porter*, will find the various *additions* which are said to be made to those liquors prescribed in various "Treatises on Brewing." *Porter* derives its peculiarities from *high-dried* malt, a certain proportion of which is used in the wort; it is also coloured with *parched* malt, or other colouring-materials. As issued from the large breweries, it is a genuine and excellent liquor, but it is sadly adulterated and deteriorated by the *publicans*. In Russia, a beverage is made as a substitute for beer, which is called *quaas:* 9 parts of rye-meal, and 1 of undried rye-malt are made into a paste with water, and left for some days in a warm place, when the mass becomes quite sweet; a wort is then prepared from it, which is run off into casks, where, by the addition of a little yeast, it is brought into slow fermentation: when this terminates it is ready for use. (Berzelius.)

The wort is next boiled with *hops* (see p. 1046, *note*), amounting, upon the average, to one-twentieth the weight of the malt, their use being to cover the sweetness of the liquor by their aromatic bitter, and to diminish its tendency to acidify. The liquor is then generally thrown into large, but very shallow, vessels, or *coolers*, or by other contrivances, is cooled to about 50°, as quickly as possible; it is then suffered to run into the *fermenting-vat*, having been previously mixed with a proper quantity of *yeast*, the use of which has been above stated.

In the fermenting-vessel, the different substances held in solution in the liquor begin to act upon each other; an intestine motion ensues, the *temperature* of the liquor increases, *carbonic acid* escapes in large quantities; at length this evolution of gas ceases, the liquor becomes quiet and clear, and it has now lost much of its sweetness, has diminished in specific gravity, acquired a new flavour, and become *intoxicating* from the presence of *alcohol.*

WASH. The distillers prepare a liquor, called *wash*, for the express purpose of producing from it ardent spirits; instead of brewing this from pure malt, they chiefly employ raw grain, mixed with a small quantity only of malted grain; the water employed in the mash-tun is of a lower temperature than that requisite in brewing, and the mashing longer continued; by which the starch of the barley is rendered into gum and saccharine matter. The wort is afterwards fermented with yeast*.

WINE. *Wine*, properly so called, is exclusively derived from the juice of the grape. The principal substances held in solution in grape-juice are *sugar*, *gum*, *gluten*, and *bitartrate of potassa*†. It easily ferments spontaneously at temperatures between 60° and 80°, and the phenomena it gives rise to closely resemble those of the wort with yeast*. After the operation, its specific gravity is much diminished, its flavour changed, and it has acquired intoxicating powers, from the cause before mentioned, namely, the formation of alcohol.

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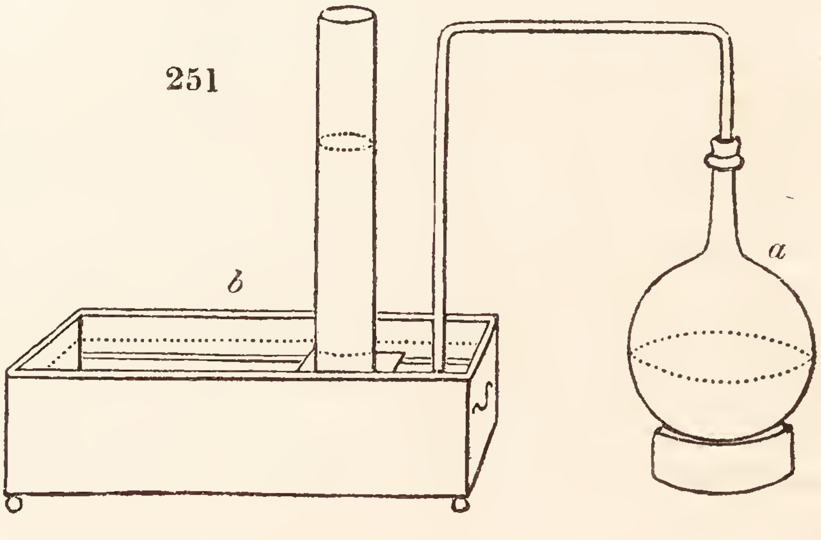
* All the operations of our distilleries would be susceptible of infinite improvement by an alteration in the excise-laws: as these at present stand, the duty is charged from calculations, 1. On the quantity and density of the *wash;* 2. On the quantity and density, or strength of the *low wines,* or first products of distillation; 3. Upon the quantity and strength of the *spirit,* or, in other words, of the *alcohol* actually produced: it is presumed, in reference to the *wash,* that the alcohol which it will afford by fermentation will be directly as its *density* (without reference to the *nature* of the matter which it holds in solution). In the low wines, and in the spirits, the proportion of alcohol is inversely as the density, and the duty is charged in conformity with experiments upon the composition of mixtures of alcohol and water of different densities. I say nothing here of the mode of judging of the value of the wort by its *attenuation* during fermentation, nor of the fallacies to which the different operations are liable, and I am well aware of the danger and difficulties of meddling with so important a branch of the revenue; but I think it impossible for any scientific person to visit our distilleries without at once seeing much that is susceptible of safe and effectual alteration; or to peruse the multitudinous documents, and the evidence which has been brought before the Commissioners' of Revenue Inquiry and before Parliamentary Committees, bearing directly or indirectly upon this subject, without an anxious wish that some remedy should be found for the evils which are there set forth. In every point of view, two things seem highly desirable, and apparently not unattainable; the one is, that the materials employed as sources of spirit, and the mode of conducting the operations of the distillery, should be, as far as possible, entirely unshackled; the other (a necessary consequence), that the duty should be levied upon *the ultimate produce at the worm-end,* or, in other words, upon *the quantity of absolute alcohol* actually produced, and that the charge should be made in reference to that alone.

† A very curious modification of tartaric acid has been discovered by Mr. Kœstner, of Thann, and examined by Gay Lussac, Walchner, and Berzelius, (*Ann. de Chim. et Phys*, xlvi., 128,) who terms it *paratartaric acid:* it has been called *racemic acid,* and supposed to be peculiar to certain grapes. This acid is less soluble than tartaric acid, and its crystals instead of *one,* include *two* atoms of water, one of which is given off at 212°, and the other, when it unites with bases. It is obtained by neutralizing the tartar which contains it with soda, and separating the double *tartrate* of soda and potassa by crystallization; the double *racemate* remains in the mother-liquor, which, filtered through animal charcoal, and decomposed by a solution of acetate of lead, yields a mixed tartrate and *racemate of lead;* these, diffused through water and decomposed by sulphuretted hydrogen, furnish a solution of racemic and tartaric acids, from which the former may be perfectly separated by crystallization, whilst the latter remains in the mother-liquor. *Anhydrous racemic acid* is represented by $(4\,car + 2\,h + 5\,o) = rac'$; and the *crystallized* by $(rac' + 2\,q)$.

Liquors, under the name of *wine*, are frequently made from *currants*, *gooseberries*, and other fruits, and when very carefully prepared they are not only palatable but excellent. But it is seldom that the requisite attention is paid to their manufacture, (see Macculloch on Wines,) and they derive at all times a peculiarity from the presence of malic and citric acids, which are retained in solution; whereas, in grape-juice, the acid is chiefly in *tartar*, which is precipitated in proportion as alcohol is formed, and not retained in any quantity, especially in old wines. *Made wines*, as they are termed, are generally very strong, in consequence of the quantity of sugar which is used in their production; a considerable proportion of brandy is also often added to them, to prevent secondary fermentation. *Perry* and *cyder* are the fermented juices of *pears* and *apples*, and vary in flavour, strength, and quality, according to the quality of the fruit, and the extent to which the fermentation is carried. *Mead* is a vinous liquor made by dissolving 1 part of honey in 2 and two-thirds of boiling-water, and adding spices, such as cloves, nutmegs, &c., and a portion of ground malt, and piece of toasted bread dipped in yeast, and suffering the whole to ferment; the Scandinavian mead, according to Berzelius, was flavoured with primrose-blossoms.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The changes of the various substances concerned in fermentation, can only be fully explained and understood, when the nature of *alcohol* has been examined, but an instructive experiment in reference to this may be made by introducing a mixture of 1 part of sugar, 4 or 5 of water, and a small quantity of yeast, into the bottle *a*, represented in the annexed cut (fig. 251); this mixture gives rise to the same products as *wort* or *grape-juice:* a bent tube issues from the bottle, passing under the inverted jar placed in the water-trough *b*. It will now be found, that all that is requisite to induce fermentation, and the consequent production of alcohol from the above materials, is to subject them to a *due temperature*, say between 70° and 80°; they then soon begin to act upon each other, and the principal points to be noticed are, 1. that *carbonic acid* is evolved (without the contact of oxygen or of the external air); 2. that the *sugar* gradually disappears; and, 3. that *alcohol* is gradually formed. Now the inference which we should at once draw from this experiment, and it is not an incorrect one, is, that sugar, *minus* carbonic acid, produces alcohol, for as we shall afterwards find, we have no evidence of the decomposition of water in the process, or of any other source of oxygen than the sugar itself, and it alone can yield the carbon. I have, for the present, put the action of the yeast out of the question, for we shall find it not essential to the theory of the process. The alcohol remains almost entirely in the receiver, in combination with the water, and any other matters that may have accidentally been present; a little, and but a little of it, passes off along with the carbonic acid gas, and this, together with other considerations, renders it advisable in all cases to carry on fermentation with as little access of air as possible, and to allow of the escape of the carbonic acid by a comparatively small vent, and even in some cases to pass it into cold water, with a view of collecting, if not the alcohol, the *aroma*, which may sometimes be serviceably applied.

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* A question naturally suggests itself here, why the juice of the grape does not ferment in the fruit itself? We know that ripe grapes, even cut from the vine, exhibit no such tendency; they dry up and shrivel, becoming ultimately *raisins*, but never fermenting, so long as the skin is entire. It was once supposed that this arose from the *gluten* or *ferment* being in distinct vesicles or cells from those containing the *saccharine juice*, and that consequently no fermentation could ensue till the fruit was mashed or broken so as to mix these ingredients. But Gay Lussac found that when grapes were bruised, carefully *excluded from air*, no change ensued; but that even a momentary exposure of the pulp to air or oxygen, was enough to communicate to it the power of fermentation. This seems to arise from some recondite action of oxygen on the glutinous principle of the grape, by absorbing which it acquires the properties belonging to *yeast*. It is curious how perfectly the exclusion of *air* is provided for by the natural texture of the grape, which does not allow its ingress, although it admits of the transpiration of *aqueous vapour*, as is shown by the spontaneous desiccation of the berry.

BRANDY, &c. When wine, or any of the above-mentioned fermented liquors are distilled, they afford a *spirituous liquor;* that from wine is termed *brandy;* from the fermented juice of the sugar-cane we obtain *rum;* and from wash, *malt spirit;* and these spirituous liquors, by redistillation, furnish *spirit of wine*, *ardent spirit*, or *alcohol**.

The different fermented liquors furnish very different proportions of alcohol, and it has been sometimes supposed that it does not *pre-exist* to the amount in which it is obtained by distillation (Fabbroni, *Ann. de Chim.*, xxx.): but some experiments which I made upon the subject, in 1811 and 1813, (printed in the *Phil. Trans.* for those years,) tend to show that it is a real *educt*, and not *formed* by the action of heat upon the elements existing in the fermented liquor†.

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* I am obliged here, for want of space, to omit all details respecting the production of brandy and other spirits, the *forms of stills*, and the operations of the *rectifier*.

† I regret that in the experiments, the results of which are contained in the *table* in the text, I did not throughout determine the specific gravity of the wine *before* as well as after distillation, and that the other contents of the wine were not accurately ascertained, for, although these points were made out in some cases, they were not accurately attended to throughout. The following are two of these results:

1. CAPE WINE.

Sp. gr. *before* distillation	.9824
Ditto *after* ditto	.9742
Alcohol *per cent.*	23.61

2. SHERRY.

Sp. gr. *before* distillation	.9879
Ditto *after* ditto	.9762
Alcohol *per cent.*	21.34

See also the tables of the strength of wines in Dr. Henderson's work.

The following Table exhibits the proportion of alcohol, specific gravity .825 at 60°, by measure, existing in 100 parts of several kinds of wine and other liquors:

		Proportion of Spirit *per cent* by Measure.
1.	Lissa	26.47
	Ditto	24.35
	Average	25.41
2.	Raisin wine	26.40
	Ditto	25.77
	Ditto	23.20
	Average	25.12
3.	Marsala	26.03
	Ditto	25.05
	Average	25.09
4.	Port	25.83
	Ditto	24.29
	Ditto	23.71
	Ditto	23.39
	Ditto	22.30
	Ditto	21 40
	Ditto	19.00
	Average	22.96
5.	Madeira	24.42
	Ditto	23.93
	Ditto (Sercial)	21.40
	Ditto	19.24
	Average	22.27
6.	Currant wine	20.55
7.	Sherry	19.81
	Ditto	19.83
	Ditto	18.79
	Ditto	18.25
	Average	19.17
8.	Teneriffe	19.79
9.	Colares	19.75
10.	Lachryma Christi	19.70
11.	Constantia, white	19.75
12.	Ditto, red	18.92
13.	Lisbon	18.94
14.	Malaga	18.94
15.	Bucellas	18.49
16.	Red Madeira	22.30
	Ditto	18.40
	Average	20.35
17.	Cape Muschat	18.25
18.	Cape Madeira	22.94
	Ditto	20.50
	Ditto	18.11
	Average	20.51
19.	Grape wine	18.11
20.	Calcavella	19.20
	Ditto	18.10
	Average	18.65
21.	Vidonia	19.25
22.	Alba Flora	17.26
23.	Malaga	17.26
24.	White Hermitage	17.43
25.	Rousillon	19.00
	Ditto	17.26
	Average	18.13

		Proportion of Spirit *per cent.* by Measure.
26.	Claret	17.11
	Ditto	16.32
	Ditto	14.08
	Ditto	12.91
	Average	15.10
27.	Zante	17.05
28.	Malmsey Madeira	16.40
29.	Lunel	15.52
30.	Sheraaz	15.52
31.	Syracuse	15.28
32.	Sauterne	14.22
33.	Burgundy	16.60
	Ditto	15.22
	Ditto	14.53
	Ditto	11.95
	Average	14.57
34.	Hock	14.37
	Ditto	13.00
	Ditto (old in cask)	8.88
	Average	12.08
35.	Nice	14.63
36.	Barsac	13.86
37.	Tent	13.30
38.	Champagne (still)	13.80
	Ditto (sparkling)	12.80
	Ditto (red)	12.56
	Ditto (ditto)	11.30
	Average	12.61
39.	Red Hermitage	12.32
40.	Vin de Grave	13.94
	Ditto	12.80
	Average	13.37
41.	Frontignac (Rivesalte)	12.79
42.	Côte Rôtie	12.32
43.	Gooseberry wine	11.84
44.	Orange wine — average of six samples made by a London manufacturer	11.26
45.	Tokay	9.88
46.	Elder wine	8.79
47.	Cider, highest average	9.87
	Ditto, lowest ditto	5.21
48.	Perry, average of 4 samples	7.26
49.	Mead	7.32
50.	Ale (Burton)	8.88
	Ditto (Edinburgh)	6.20
	Ditto (Dorchester)	5.56
	Average	6.87
51.	Brown Stout	6.80
52.	London Porter (average)	4.20
53.	Ditto Small Beer (ditto)	1.28
54.	Brandy	53.39
55.	Rum	53.68
56.	Gin	57.60
57.	Scotch Whiskey	54.32
58.	Irish ditto	53.90

The wines employed in the experiments upon which the preceding table is founded, were selected with all possible caution as to purity and quality; a given measure of each (saturated, when necessary, with lime or potassa) was carefully distilled nearly to dryness, and the bulk of the distilled product was exactly made equal to that of the original wine by the addition of distilled water. After twenty-four hours its specific gravity was determined, and thence the quantity of alcohol, by reference to *Gilpin's tables*. The management of this and similar distillations is well described by Mr. Faraday. (*Manip.*)

The change which wine undergoes *in the cask*, is sometimes connected with a continuance of the fermentation, during which it deposits *tartar* in combination with a peculiar glutiniferous extractive and colouring-matter, the terms *red* and *white* tartar being applied to its varieties: the solvent power of the wine over tartar diminishes in proportion to the alcohol which it contains, so that the strongest wines are always in this respect the least acid*. *In bottles* the same changes continue as in the cask, but they are extremely slow and imperfect; the wine, however, deposits its crust of glutinous extractive and tartar; and it is not uncommon to find in many wines, which have been long in bottle, crystals of tartar, and also of bitartrate of lime, the proportion of all which varies in different wines, and in the same wine according to the time which it had previously been kept in the cask. Another character of wine which is also much influenced by its age in bottle, is that refined and delicate flavour and odour, termed *bouquet*, or perfume, and upon which so much of the excellence and consequent value of some kinds of wine depends. This quality seems sometimes to depend upon the production of a species of volatile oil, and in others, upon the formation of something ethereal, but it is so fleeting and destructible, that we have nothing but surmise to offer upon that subject. There is no apparent limit to the time for which some wines may be kept not only in a perfect, but apparently in an improving state, in bottle; such especially are *madeira* and *sherry*. Many of the red wines go on for a time improving, in consequence of the deposition of extractive, tannin, and tartar; they then deteriorate, losing colour and flavour; this is the case with *port*. The aroma or bouquet of *claret* is much improved, up to a certain point, and is then apt gradually to decline; yet, the deposit from that wine, or the apparent change which it suffers in bottle, is remarkably small: I have seen it after twenty-five years to have deposited nothing more than a thin transparent film of colouring extractive, nearly equal on the whole of the interior of the bottle, together with a slight sediment of the bitartrates of lime and potassa. Some of the rich sweet wines acquire a flavour slightly resembling that of acetic ether after remaining many years in bottle, and during this change they become less and less saccharine.

The *effervescent wines* are bottled before the fermentation, as relating to the formation of carbonic acid, is complete; the consequence is, that

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* In cask, too, the wine is changed by evaporation, and the pores of the wood seem to admit of the passage of *aqueous* vapour, whilst, as is the case with bladder, they oppose the transpiration of *alcoholic* vapour, so that whilst wine in the wood, diminishes in bulk, it probably increases in strength.

that gas continues to be formed, and is necessarily retained by and compressed in the wine. Some of these wines are liable to become *ropy;* the glutinous part of the juice not having been entirely decomposed, in consequence of the incomplete fermentation, separates in the form of a viscid matter, not unlike white of egg. Pure tannic acid, prepared according to Pelouze's method, (see p. 927,) is said by Dumas to prevent this effect; or even the addition of powdered galls, to the wine before bottling.

The *colour of wines* arises from various causes. *Red wines* derive their colour from the purple husk or skin of the grape, the colouring-matter of which becomes soluble in proportion as alcohol is developed, and is reddened by the acid of the juice: tannin is derived from the same source, and perhaps sometimes from the seeds; this gives to red wines their astringency and action on the salts of iron. Some *white wines*, Sauterne, and Barsac especially, and I think some of the Rhenish wines, become brown or even blackish, after a few hours exposure to air, which arises either from the presence of some modification of tannin, or from their containing together with that principle, a trace of some protosalt of iron, which, by the action of the air, becomes peroxidized, and gives the colour. The yellow or brown colour of what are called *white wines*, arises from extractive matter; it is also frequently artificial, and the greater part of *brown sherry* is tinted by burned sugar. The colour of *red wines* is also often communicated by various additions, respecting which, and the means of detecting them, some details will be found in Berzelius's Chemistry. (iii. 949, Wöhler's edition.)

ALCOHOL. This term, which is of Arabic origin, is applied to the intoxicating principle of vinous and spirituous liquors, a fragrant limpid liquid, the properties of which we shall proceed to examine. The history of alcohol is obscure, but its discovery is generally attributed to Raymond Lully, or to Arnold of Villa Nova, or Villeneuve, a chemist who resided at Montpellier, in 1300; but inasmuch as the Egyptians seem to have derived their chemical knowledge from the Oriental nations, and as we know that distillation was practised by them at a very remote period, it is more than probable, that alcohol was amongst their numerous discoveries.

The *spirit of wine* of commerce, is alcohol diluted by a variable proportion of water, and generally containing traces of a peculiar *volatile oil*, formed apparently during fermentation, and obstinately retained by the spirit. It is from this source that we obtain *pure* or *anhydrous*, or as it is often called, *absolute alcohol;* for this purpose various methods are pursued, among which the following are preferable.

Put some pure lime, which has been well burned, into an alembic or retort, and pour upon it whilst yet warm, its weight of spirit of wine, leaving the mixture for 24 hours, and then proceeding to distil it slowly at a temperature below 212°. The first portions which pass over are *pure alcohol*, the last portions, especially if the spirit was not very strong, are apt to contain water, and should therefore be kept apart. The alcohol may be regarded as anhydrous, when its specific gravity is not diminished by a repetition of the distillation. (Gay Lussac, *Ann. de Chim.*, lxxxvi., 175, xcv., 311. *Ann. de Chim. et Phys.*, ii., 130.) Acetate, tartrate, or carbonate of potassa are sometimes used to deprive alcohol of water, but they are not so effective as lime. When carbonate of potassa is used, it should be added warm to the spirit, and the mixture well stirred or shaken; such quantity is requisite as to leave a small portion of the salt undissolved: upon standing at rest, the mixture soon separates into two portions: the uppermost is the alcohol; the lower, an aqueous solution of the carbonate: the alcoholic portion being carefully decanted from the residue, is to be put into a retort, and about three-fourths of it distilled over at a moderate heat into a cooled receiver. Dry chloride of calcium may also be used, and is a very effective agent for the separation of the water from alcohol. Caustic potassa is sometimes employed, but it acts chemically upon the alcohol itself. Dried sulphate of lime, sulphate of soda, and some other anhydrous salts eagerly absorptive of water, have also been proposed, but they are inadequate to the total abstraction of the water.

When spirit of wine is put into a bladder, or into a glass vessel with a wide mouth, tied over with bladder, it is found that the aqueous vapour penetrates the animal membrane, in preference to the alcoholic vapour, so that the spirit, by spontaneous evaporation, becomes thus concentrated within the bladder or vessel; spirit of the specific gravity of .867, was thus easily reduced to .817. (*Quarterly Journal*, viii. 381, and xviii. 180.) But this, though a curious experiment, in illustration of the passage of vapours through membranes, is, at all events, only adapted to strengthen common spirit, and not to the preparation of pure alcohol*.

Professor Graham has ingeniously proposed to concentrate alcohol as follows. (*Edinb. Phil. Trans.*, 1828.) A shallow vessel is sprinkled over with coarsely-powdered quicklime, and a smaller one containing spirit of wine is placed just above it; both are covered by a proper bell-glass, upon the plate of an air-pump, and the air exhausted till the alcohol begins to boil. Of the vapour which rises, the lime only absorbs the aqueous part, and as water cannot remain under these circumstances in alcohol, unless covered by an atmosphere of its own vapour, it continues in uninterrupted evaporation, whilst the escape of alcohol is prevented by the pressure of its own unabsorbed vapour. If sulphuric acid be substituted as the absorbent instead of quicklime, it absorbs both vapours, and the whole of the spirit evaporates.

Pure alcohol is a limpid, colourless liquid, of an agreeable smell, and a strong pungent flavour. From its action on the system it may be termed *poisonous;* when more or less dilute it is *intoxicating.* The mode in which it kills animals, and the physiology of inebriation have been studied by Orfila and by Sir B. Brodie. (*Phil. Trans.*) It is considerably lighter than water. Its specific gravity varies with its purity; the purest obtained by rectification over lime, or *absolute alcohol*, being .791; as it usually occurs it is .820, at 60°. If rendered as pure as possible by *simple* distillation, it can scarcely be obtained of a lower specific gravity than .825, at 60°. The London Pharmacopœia states *rectified spirit* to have the specific gravity of .835. Alcohol is sufficiently volatile to produce considerable cold during evaporation, though in this respect much inferior to ether. The degree of cold is proportional to the purity of the alcohol. (*Quarterly Journal*, x. 187.)

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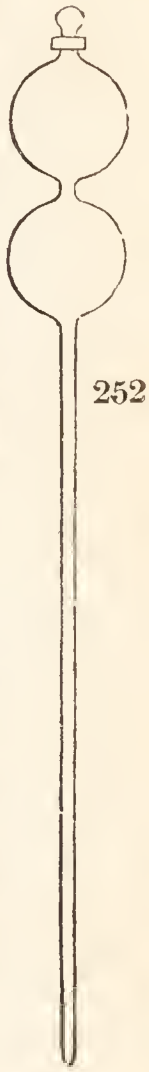
* Smugglers, who bring spirits into Paris in bladders concealed about their persons, have long known, that although it lost bulk, it acquired strength: hence the preference given to this contraband article.

Alcohol has never been frozen, and consequently is particularly useful in the construction of thermometers intended to measure intense degrees of cold. Alcohol of the specific gravity of .7947, boils at 173°. (Barom. 29.5.) When of a specific gravity of .825, it boils at the temperature of 176°, the barometrical pressure being 30 inches. When its specific gravity is as low as .800, its boiling-point is 173.5°; and when raised by the addition of water to a specific gravity of .900, its boiling-point, according to Dalton, is elevated to 182°. A table of the boiling-points of various mixtures of alcohol and water, founded on M. Groening's experiments, is giving in the *Annals of Philosophy*, *N. S.*, v. 313. In the vacuum of an air-pump alcohol boils at common temperatures. The specific gravity of the *vapour of alcohol* compared with atmospheric air, is 1.613. (Gay Lussac, *Ann. de Chim. et Phys.*, i.) One volume of alcohol produces 488.3 volumes of vapour, calculated at the temperature of 212°. According to Berzelius and Dulong, the density of the vapour of anhydrous alcohol is 1.6004. (*Ann. de Chim. et Phys.*, xv.) To become vapour, alcohol absorbs only 0.436, the heat required to evaporate an equal weight of water. According to Despretz, the latent heat of alcoholic vapour is to that of steam, as 331.9 to 531. Dr Ure, (*Phil. Trans.*, 1818,) has given a table of the forces of vapour of alcohol at different temperatures. The expansibility of alcohol by heat is such, that 1000 parts, (specific gravity .817,) at 50°, becomes 1079 parts at 170°. At 110°, half-way between the extremes, the alcohol was at 1039, or half a division below the true mean. The more the alcohol is diluted with water, the greater Mr. Dalton found the disproportion to be between the two parts of the scale. When of the specific gravity .967, corresponding to 75 *per cent.* of water, the ratio of expansion through the first half between 50° and 170°, was to that through the second half, as 35 to 45. (*Henry's Elements*, ii., 319; 9th edit.) The following table of the contraction of alcohol in cooling down from its boiling-point, is given by Dumas, as founded upon Gay Lussac's experiments.

Temp.		
Cent.	Fahr.	Volume.
78.14°	173°	1000.0
73.4	164	994.4
68.4	155	988.6
63.4	146	982.5
58.4	136	975.7
53.4	128	970.9
48.4	119	965.3
43.4	110	960.0
38.4°	101°	954.4
33.4	92	948.9
28.4	83	943.6
23.4	73	938.6
18.4	65	934.0
13.4	56	929.3
8.4	47	924.5
3.4	39	919.9

Alcohol has a strong affinity for water, and at common temperatures absorbs a little of the aqueous vapour of the atmosphere. It may be mixed in all proportions, with water, and the specific gravity of the mixture is greater than the mean of the two liquids, in consequence of the *diminution of bulk* that occurs on mixture; this may be shown by the following experiment:—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The annexed wood-cut represents a tube with two bulbs, communicating with each other, the upper one being supplied with a well-ground glass stopper. Fill the tube and lower bulb with *water*, pour *alcohol* slowly into the upper bulb, and when full put in the stopper. The vessel will now be completely filled, the alcohol lying upon the water; if it be inverted, the alcohol and water will slowly mix, and the condensation that ensues will be indicated by the empty space in the tube. A considerable rise of temperature takes place in this experiment, in consequence of the condensation. Thus, equal measures of alcohol (of a specific gravity of .825) and water, each at 50°, afford, when suddenly mixed, a temperature of 70°; and equal measures of proof-spirit and water, each at 50°, give, under similar circumstances, a mixture of the temperature of 60°.

When alcohol and water are mixed, the contraction increases till the mixture consists of 100 parts of alcohol and 116.23 of water. According to Rudberg, 100 volumes of this mixture, at 59°, contain 53.739 volumes of anhydrous alcohol, and 49.836 of water, the condensation therefore amounts to 3.575. The specific gravity is 0.927 at 59°. Departing from this point, the contraction produced by fresh additions of water becomes more and more feeble, and terminates in apparent dilatation: thus Tillaye found, that when equal volumes of dilute alcohol, specific gravity 0.954, and water, were mixed, the specific gravity became 0.9768, whereas, if there had been no expansion, the density would have been 0.9772. The following table calculated by Rudberg, from the experimental results of Gay Lussac and Tralles, further illustrates this subject. (*Ann. de Chim. et Phys.*, xlviii. 33.)

Volume of Alcohol *per cent.*	Contraction, in hundredths of the volume, of the mixture.
100	0.
95	1.18
90	1.94
85	2.47
80	2.87
75	3.19
70	3.44
65	3.615
60	3.73
55	3.77
50	3.745
45	3.64
40	3.44
35	3.14
30	2.72
25	2.24
20	1.72
15	1.20
10	0.72
5	0.31

In reference to this table, Dumas remarks, that the maximum of contraction indicates 55 *per cent.* of alcohol, but that Rudberg's experiments place it at 54 *per cent.*, which is equivalent by weight to 1 atom of alcohol and 3 atoms of water, or 23 + 27.

The absolute amount of the contraction varies with the temperature; according to Tralles, at 39° it amounts to 3.97; at 52° to 3.77; at 64° to 3.60; and at 100° to 3.31. (See also Gilpin's *Tables*, in reference to this subject.)

The *strength* of such spirituous liquors as consist of water and alcohol, is ascertained by their *specific gravity*[*], and for the purpose of levying duties upon them, this is determined by the *hydrometer;* but the only correct mode of ascertaining the specific gravity of liquids, is by weighing them in a delicate balance, against an equal volume of pure water, of a similar temperature. (See p. 136.)

The facilities, however, in using the *hydrometer* are such as to render it best fitted for the practical purposes of the excise, and, consequently, the Committee of the Royal Society have recommended to the government a form of this instrument, which they consider best adapted to the purpose, accompanied by proper tables; from their *report* (drawn up by Mr. Faraday), I make the following extract, which will explain the most important parts of the inquiry relating to the composition and density of PROOF SPIRIT[†].

" With regard to the substance, *alcohol*, upon which the excise duty is to be levied, there appears to be no reason, either philosophical or practical, why it should be considered as *absolute*. A definite mixture of alcohol and water is as invariable in its value as absolute alcohol can be. It is also invariable in its nature; and can be *more readily*, and with equal accuracy, identified by that only quality or condition to which recourse can be had in practice, namely, specific gravity. A *diluted alcohol* is, therefore, that which is recommended by us as the only exciseable substance; and as, on the one hand, it will make no difference in the identification, and on the other, will be a great commercial advantage, it is further recommended that the standard be very nearly that of the present proof-spirit.

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[*] There are other methods of judging of the strength of spirituous liquors, which, though useful, are not accurate, such as the taste, the size and appearance of the bubbles when shaken, the sinking or floating of olive-oil in it, and the appearances that it exhibits when burned; if it burns away perfectly to dryness, and inflames gunpowder or a piece of cotton immersed in it, it is considered as *alcohol*. The different spirituous liquors leave variable proportions of water, when thus burned in a graduated vessel. But it must be recollected that in rum, brandy, and several other spirits, the specific gravity is often interfered with by extractive, colouring, and saccharine substances, often *fraudulently* added with a view to diminish their apparent strength. In examining these liquors, they should be *distilled* in the manner described above in reference to wine, and the specific gravity of the *distilled portion* will then give an indication of the proportion of alcohol *per cent.* that may be relied on. In respect, however, to the *excise, distillation* is inconvenient, and is, therefore, I believe, only resorted to in extreme or very suspicious cases.

[†] Hitherto the term *proof-spirit* has been but indefinitely employed. Dr. Thomson, quoting the act of parliament of 1762, states, that at the temperature of 60°, the specific gravity of proof-spirit should be 0.916; and he also observes that *proof-spirit* usually means a mixture of *equal bulks* of alcohol and water; but the specific gravity of such a mixture will, of course, depend upon that of the *standard alcohol*, which is not specified. It appears from Gilpin's *Tables*, that spirit of the specific gravity .916, at 60°, consists, *by weight*, of 100 parts of alcohol, specific gravity .825, at 60°, and 75 of water; and, *by measure*, of 100 parts of the same alcohol, and 61.87 of water. From the *Tables* of Lowitz, quoted by Dr. Thomson, from Crell's *Annals* (1796, i., 202), equal weights of alcohol, specific gravity .796, at 60° (and which may be regarded as *pure alcohol*), and water, have a specific gravity of .917, which is very near legal proof, and which, according to Gilpin's *Tables*, contains 62.8 parts *per cent.* of his alcohol, *by measure*. The *proof-spirit* of the *Pharmacopœia* (*spiritus tenuior*) is directed to be of the specific gravity .930.

"The proposition of your committee is, that *standard spirit* be that which, consisting of alcohol and water alone, shall have a specific gravity of 0.92 at the temperature of 62° Fahr., water being unity at that same temperature; or, in other words, that it shall at 62° weigh $\frac{92}{100}$ths, or $\frac{23}{25}$ths of an equal bulk of water at the same temperature. The temperature of 62° Fahr. is recommended as the standard, because it is that at which water was taken in the late national survey and adjustment of weights and measures. The specific gravity of 0.92 is taken rather than 0.918633 (the specific gravity of present proof-spirit at 62°), because the fraction expressing its relation to water is much more simple, and will facilitate the construction of the tables and the verification of the instruments proposed to be used.

"This definition of *standard spirit* appears to your committee to be very simple, and yet as exact as it can be, or as any *other* standard spirit can be. This standard is rather weaker than the old *proof-spirit*, in the proportion of nearly 1.1 gallon of the present proof-spirit per cent. But this disadvantage your committee consider as trifling compared with the great convenience which will result if the specific gravity of 0.92 be taken rather than 0.918633.

"It may be interesting hereafter to ascertain what proportion of *absolute alcohol* enters into the composition of the recommended standard spirit, should the latter be adopted by the government; but the point possesses not the slightest practical importance in relation to the present question. The proposed standard is in fact more definite, more sure, and more ascertainable than that of the alcohol which it must contain. Philosophers are not yet agreed upon absolute alcohol, and the differences of specific gravity assigned at 60° vary from .7910 to .7980. But assuming the truth to be somewhere within these extremes, the proposed standard would contain nearly one-half by weight of absolute alcohol: .7947 *at* 59°, *Berzelius;* .7960 *at* 60°, *Turner from Saussure?* .7910 *at* 60°, *Brande;* .7980 *Chaussier;* .79235 *at* 64°, *Gay Lussac.*

"In any mixture of alcohol and water the *specific gravity* appears to be the only quality or condition to which recourse can be had for the practical purposes of the excise, in order to indicate the proportion of standard spirit present. Your committee are of opinion that the *hydrometer* is the instrument best fitted in the hands of the excise-officer to indicate that specific gravity; and they think it ought to be so graduated as *to give the indication of strength, not upon an arbitrary scale, but in terms of specific gravity at a fixed temperature, which, in the present case, should be* 62°, or that of the standard spirit. The graduation in terms of specific gravity will not only supply a very minute yet sensible scale for the purpose of ascertaining smaller differences in the density than is done by the present scale, but will also afford an easy means of verifying the instruments when required."

In the *Philosophical Transactions* for 1794, Mr. Gilpin has given a copious and valuable series of tables of the specific gravity of mixtures of alcohol and water, and of the condensation that ensues, with several other particulars. These are extremely useful, as enabling us to ascertain, without difficulty, the relative quantity of alcohol contained in any mixture of known specific gravity. The original tables are very voluminous, and have been variously abridged; but as they are published separately, they should be in the hands of all persons engaged in these inquiries. As far as the experimental chemist is concerned, the following table, by Lowitz, will probably be found sufficient. It shows the quantity of *absolute alcohol* (specific gravity .7960 at 60°) contained in diluted alcohol of different specific gravities*.

100 parts.		Sp. Gravity.		100 parts.		Sp. Gravity.		100 parts.		Sp. Gravity.	
Alc.	Wat.	At 68°.	At 60°.	Alc.	Wat.	At 68°.	At 60°.	Alc.	Wat.	At 68°.	At 60°
100	0	0·791	0·796	66	34	0·877	0·881	32	68	0·952	0·955
99	1	0·794	0·798	65	35	0·880	0·883	31	69	0·954	0·957
98	2	0·797	0·801	64	36	0·882	0·886	30	70	0·956	0·958
97	3	0·800	0·804	63	37	0·885	0·889	29	71	0·957	0·960
96	4	0·803	0·807	62	38	0·887	0·891	28	72	0·959	0·962
95	5	0·805	0·809	61	39	0·889	0·893	27	73	0·961	0·963
94	6	0·808	0·812	60	40	0·892	0·896	26	74	0·963	0·965
93	7	0·811	0·815	59	41	0·894	0·898	25	75	0·965	0·967
92	8	0·813	0·817	58	42	0·896	0·900	24	76	0·966	0·968
91	9	0·816	0·820	57	43	0·899	0·902	23	77	0·968	0·970
90	10	0·818	0·822	56	44	0·901	0·904	22	78	0·970	0·972
89	11	0·821	0·825	55	45	0·903	0·906	21	79	0·971	0·973
88	12	0·823	0·827	54	46	0·905	0·908	20	80	0·973	0·974
87	13	0·826	0·830	53	47	0·907	0·910	19	81	0·974	0·975
86	14	0·828	0·832	52	48	0·909	0·912	18	82	0·976	0·977
85	15	0·831	0·835	51	49	0·912	0·915	17	83	0·977	0·978
84	16	0·834	0·838	50	50	0·914	0·917	16	84	0·978	0·979
83	17	0·836	0·840	49	51	0·917	0·920	15	85	0·980	0·981
82	18	0·839	0·843	48	52	0·919	0·922	14	86	0·981	0·982
81	19	0·842	0·846	47	53	0·921	0·924	13	87	0·983	0·984
80	20	0·844	0·848	46	54	0·923	0·926	12	88	0·985	0·986
79	21	0·847	0·851	45	55	0·925	0·928	11	89	0·986	0·987
78	22	0·849	0·853	44	56	0·927	0·930	10	90	0·987	0·988
77	23	0·851	0·855	43	57	0·930	0·933	9	91	0·988	0·989
76	24	0·853	0·857	42	58	0·932	0·935	8	92	0·989	0·990
75	25	0·856	0·860	41	59	0·934	0·937	7	93	0·991	0·991
74	26	0·859	0·863	40	60	0·936	0·939	6	94	0·992	0·992
73	27	0·861	0·865	39	61	0·938	0·941	5	95	0·994	
72	28	0·863	0·867	38	62	0·940	0·943	4	96	0·995	
71	29	0·866	0·870	37	63	0·942	0·945	3	97	0·997	
70	30	0·868	0·872	36	64	0·944	0·947	2	98	0·998	
69	31	0·870	0·874	35	65	0·946	0·949	1	99	0·999	
68	32	0·872	0·875	34	66	0·948	0·951	0	100	1·000	
67	33	0·875	0·879	33	67	0·950	0·953				

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* French authors are still in the inconvenient habit of referring to *Baumé's hydrometer* in speaking of the specific gravities of liquids, both lighter and heavier than water: the following tables show the real specific gravities at the temperature of 55° *Fahr.*, corresponding with the *degrees* of Baumé's instrument.

FOR LIQUIDS LIGHTER THAN WATER.

Deg.	Sp. Gr.	Deg.	Sp. Gr.	Deg.	Sp. Gr.
10	=1·000	21	= ·922	32	= ·856
11	·990	22	·915	33	·852
12	·985	23	·909	34	·847
13	·977	24	·903	35	·842
14	·970	25	·897	36	·837
15	·963	26	·892	37	·832
16	·955	27	·886	38	·827
17	·949	28	·880	39	·822
18	·942	29	·874	40	·817
19	·935	30	·867		
20	·928	31	·861		

FOR LIQUIDS HEAVIER THAN WATER.

Deg.	Sp. Gr.	Deg.	Sp. Gr.	Deg.	Sp. Gr.
0	=1·000	27	=1·230	54	=1·594
3	1·020	30	1·261	57	1·659
6	1·040	33	1·295	60	1·717
9	1·064	36	1·333	63	1·779
12	1·089	39	1·373	66	1·848
15	1·114	42	1·414	69	1·920
18	1·140	45	1·455	72	2·000
21	1·170	48	1·500		
24	1·200	51	1·547		

Alcohol is extremely inflammable, and burns with a pale-blue flame, scarcely visible in bright day-light. The heat, however, of its flame is very intense, as may be shown by suspending in it a coil of fine platinum-wire, which becomes white hot. It occasions no fuliginous deposition upon substances held over it, and the products of its combustion are carbonic acid and water, the weight of the water considerably exceeding that of the alcohol consumed. According to Saussure, jun., 100 parts of alcohol afford, when burned, 136 parts of water, the production of which may be shown by substituting the flame of alcohol for that of hydrogen, in the apparatus fig. 201; and if the tube at its extremity be turned down into a glass jar, it will be found that a current of carbonic acid passes out of it, which may be rendered evident by lime-water.

When alcohol is burned at lower temperature than that required for its inflammation, as by the action of hot platinum (p. 207), the products of its combustion are very different; the proportion of carbonic acid is less, and acetic acid is formed.

There are some substances which communicate colour to the flame of alcohol; from boracic acid it acquires a greenish-yellow tint; nitre and the soluble salts of baryta cause it to burn yellow, and those of strontia give it a beautiful rose-colour; cupreous salts impart a fine green tinge. The curious monochromatic effect of common salt has been above adverted to, (p. 206, *note.*)

Mr. Graham has shown that alcohol may, in many instances, be combined with saline bodies, forming, as it were, a substitute for water of crystallization. Such combinations may be called *alcohates.* They are obtained by dissolving the substances by heat in absolute alcohol, and are deposited as the solution cools, more or less regularly crystallized. They appear to be definite compounds, and in some of them the alcohol is retained by an attraction so powerful, as not to be evolved at a temperature of 400 or 500°. Mr. Graham has examined the alcoholic combinations of chloride of calcium, nitrate of magnesia, nitrate of lime, chloride of zinc, and chloride of manganese. (*Quarterly Journal, N. S.*, Dec., 1828.)

The action of chlorine and other halogens on alcohol, we shall consider amongst *ethers.* It dissolves nearly all the acids, giving rise to an important and varied class of compounds, resulting from their mutual action: these also will be described in the next Section, relating to *ether*: but there are also a series of curious phenomena, arising out of the mere mixture of alcohol and acids, first observed by Chevreul, and subsequently examined by Pelouze. When sulphuric acid, for instance, is mixed with alcohol, the mixture has no action upon any neutral carbonate, and yet it decomposes acetate of potassa, evolving acetic acid. A mixture of alcohol and muriatic acid does not act upon carbonate of potassa, but it decomposes the carbonates of soda, lime, strontia, and magnesia. A mixture of alcohol and nitric acid is without action upon carbonate of potassa, but it acts powerfully on carbonate of lime, and of strontia, and slowly on carbonate of soda, baryta, and magnesia. An alcoholic solution of acetic and of tartaric acid decomposes none of the carbonates: a similar solution of citric acid decomposes carbonate of potassa and of magnesia, but not carbonate of baryta, strontia, or lime; and the alcoholic solution of oxalic acid decomposes carbonate of strontia, of lime, and of magnesia, but not carbonate of potassa. The addition of a small quantity of water does not affect these mixtures, for when a saturated solution of carbonate of potassa is mixed with the alcoholic solution of acetic acid, the carbonate is precipitated without effervescence: an alcoholic solution, therefore, may appear neutral to tests, whilst, in reality, strongly acid. It is difficult to suggest an explanation of these statements.

Alcohol dissolves a small quantity of sulphur, especially at its boiling-temperature, but the greater portion is deposited, on cooling, in small brilliant crystals: the solution has a peculiar odour. When a flask of alcohol is suspended in the head of an alembic, containing sulphur, and the latter melted, so that as its vapour rises it may be condensed with that of the alcohol, a reddish-yellow liquid passes over, containing sulphuretted hydrogen: this solution becomes milky upon the addition of water, and appears to contain about a hundredth part of sulphur. A very similar solution may be obtained by passing sulphuretted hydrogen into alcohol, under slight pressure. Alcohol also dissolves phosphorus, taking up about a 240th part at its boiling-point, and retaining a 320th part when cold. This solution is luminous in the dark on exposure to air, and produces a beautiful pale, but ineffectual flame, when poured upon hot water. Carbon is insoluble in alcohol, but it dissolves carburet of sulphur, and the solution is decomposed by the alkalis, (see p. 509.)

Potassium and sodium slowly decompose alcohol at common temperatures; heated with it, they evolve carburetted hydrogen. Potassa and soda are soluble in alcohol, and it is sometimes resorted to as a means of the purification of those alkalis; after a time, however, they begin to act upon each other, and complicated changes ensue; carbonate of the alkali is formed, and carbonaceous matter evolved, on the application of heat; by their slow mutual action, acetic acid, a resin, and a species of brown extractive, appear to be formed. Ammonia and its carbonates are soluble in alcohol: it absorbs a large quantity of ammoniacal, and of several other gases. Lithia, baryta, strontia, and lime, are almost insoluble in alcohol, even in their hydrated states; so also are the fixed alkaline carbonates: their sulphurets are soluble. The greater number of the chlorides*, iodides, and bromides, which are soluble in water, are soluble also in alcohol, and with many of them definite alcoholized compounds are produced: the same is the case with some of the nitrates: but the sulphates are almost all insoluble, hence the use often made in the analysis of mixtures of salts, of the separative power of alcohol.

The uses of alcohol in the arts, and its applications to various economical purposes, are extremely numerous: to the chemist it is a most valuable species of fuel, but we are almost debarred from its use by the excise regulations; and for the same reason many manufactures, in which alcohol is an essential agent, cannot be carried on in this country. Its solvent powers, in regard to resins, oils, and other organic products, have been elsewhere noticed: its medicinal and pharmaceutical employment is also important; and as an exhilarating stimulant in wines, beer, and other fermented liquors: the mischief, on the other hand, which results from its improper use, is very extensive, as illustrated in the broken constitution of mind and body which characterizes the dram-drinker and the habitual drunkard.

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* The mutual action of chloride of platinum and alcohol has been studied by Zeise, and his inquiries seem to lead to the existence of a peculiar class of salts, of which hydrocarbon and the chlorides are the elements; he terms them *etherized salts*.

Decomposition and Component Parts of Alcohol. When alcohol is passed through a red-hot tube it is decomposed, more or less perfectly according to the temperature, and to the rapidity of its passage: the most accurate experiments upon this subject are those of T. de Saussure, (*Ann. de Chim.*, xlii. and lxxxix.;) he passed the vapour of alcohol slowly through a red-hot porcelain tube; there was deposited upon its interior a little charcoal, a volatile crystalline substance (probably naphthaline), and a brown empyreumatic oil; and gas was evolved, the specific gravity of which was 0.586, and which was a mixture of carburetted hydrogen, carbonic oxide, and hydrogen.

When alcohol-vapour and oxygen are mixed in proper proportions, and fired by an electric spark, a violent explosion ensues, and carbonic acid and water are the results: 1 volume of alcohol-vapour requires 3 volumes of oxygen for its perfect combustion, and the result is, 2 volumes of carbonic acid, and 3 volumes of aqueous vapour.

Dumas and Boullay analyzed alcohol by oxide of copper (*Ann. de Chim. et Phys.*, xxxvi. 294), and the results of their experiments, with those of other analysts (corrected for absolute alcohol), give the following as the composition of this fluid:

				Saussure.	Dumas and Boullay.
Carbon	2	12	52.18	51.98	52.17
Hydrogen	3	3	13.04	13.70	13.31
Oxygen	1	8	34.78	34.32	34.52
Anhydrous alcohol	1	23	100.00	100.00	100.00

It has been above stated, that the specific gravity of alcohol-vapour is 1.60, and with this its calculated density, in reference to the above analysis, closely agrees, for

	Volumes.	Sp. Gr.
Carbon vapour	1.	0.8438
Hydrogen gas	3.	0.2064
Oxygen gas	0.5	0.5513
Alcohol vapour	1	1.6015

And these results, expressed in other terms, are equivalent to *olefiant gas* and *water**, or

				Vols.	Sp. Gr.
Olefiant gas	1	14	60.7	= 1	0.981
Water	1	9	39.3	= 1	0.620
Alcohol	1	23	100.0	= 1	1.601

Adopting these views of the atomic composition of alcohol, its *equivalent* is 23, but chemical authorities differ upon this subject, some representing alcohol by the equivalent 46, and considering it as a compound of 1 atom of *etherine* = 28 (see p. 489), and 2 atoms of water = 18, or a *binhydrate of etherine.* This is the atomic composition of alcohol, as given by Dumas; and it will be found, in some cases, a more convenient theoretical expression than the former. In reference, then, to the preceding statements, we may adopt any of the following representative *formulæ* for alcohol: $(2\,car + 3\,h + o)$, or $(2\,car + 2\,h) + q$, or $(4\,car + 4\,h) + 2\,q$; and the following diagrams will further illustrate them, and show the number of component atoms or volumes that are condensed in 1 atom of alcohol, or in 1 volume of alcohol vapour*.

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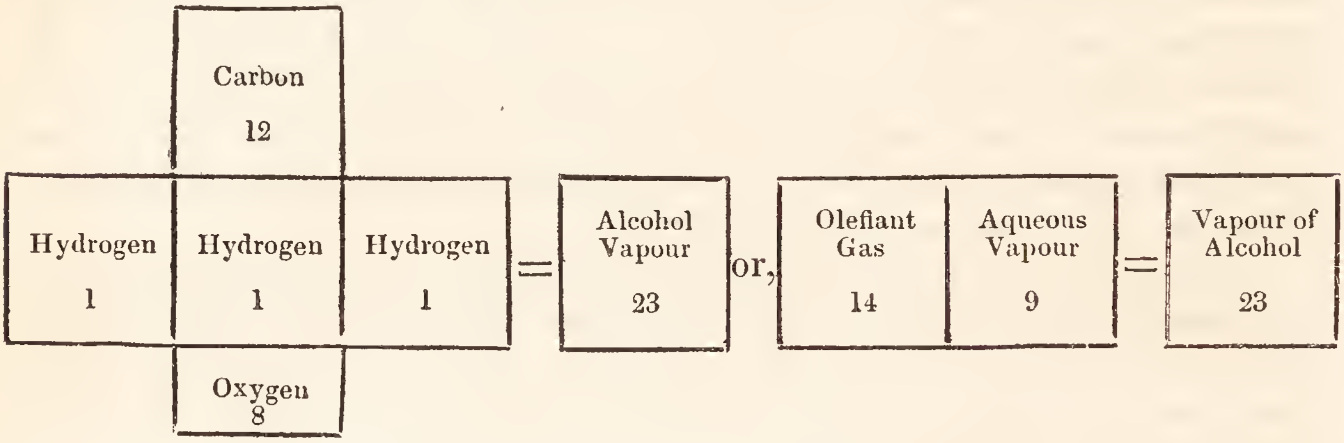
* According to Dr. Ritchie, alcohol is resolved by electrochemical decomposition into olefiant gas and water.



§ XXII. ETHER.

When mixtures of alcohol, and the stronger acids, are subjected to distillation, a liquid is formed to which the term *ether* is applied, (or by the Germans, *naphtha,*) and the nature and composition of which differs according to the acid employed; in some cases, containing the acid or its elements; and in others, not containing them. Ether of the latter description, is produced by the mutual action of alcohol and sulphuric acid, and is frequently termed *sulphuric* ether, but I shall merely term it *ether*, and shall designate those ethers which do contain the acid or one of its elements, by the acid employed, such as *nitrous*, *muriatic*, *acetic* ether, &c. The compounds which accompany the formation of the various ethers, or which are essential to their production, will also be considered in this section.

Ether. Sulphuric Ether. This liquid is first described by Valerius Cordus in 1540, under the name of *oleum vitrioli dulce.* The term

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* I have stated, in reference to the analysis of sugar, the difficulty of determining the equivalent of that compound as regards the atoms of carbon: if we adopt Gay Lussac's view of the conversion of sugar into alcohol, sugar must be regarded as a compound of 3 atoms of carbon, 3 of hydrogen, and 3 of oxygen, which, by fermentation, is resolved into 1 atom of carbon and 2 of oxygen = carbonic acid,—and into 2 atoms of carbon, 3 of hydrogen, and 1 of oxygen = alcohol; or if we adopt symbols, the change would stand as follows:—

$$\overbrace{(3\,car + 3\,h + 3\,o)}^{\text{45 Sugar}} = \overbrace{(car + 2\,o)}^{\text{22 Carbonic Acid}} \overset{\text{and}}{+} \overbrace{(2\,car + 3\,h + o)}^{\text{23 Alcohol.}}$$

According to Gay Lussac, 100 lbs. of sugar should afford 51.34 of alcohol and 48.76 of carbonic acid; and the conversion of sugar, without the absorption of oxygen, into carbonic acid and alcohol, is strongly in favour of this view of its atomic constitution, and opposed to that which supposes an excess of carbon. (See p. 904.)

ether was applied to it 190 years afterwards by Frobenius, who, in a paper in the *Phil. Trans.*, described its singular properties; at the end of this paper is a note by Godfrey Hankwitz, Mr. Boyle's operator, mentioning the experiments that had been made upon it by Boyle and by Newton. Since that period the process of etherification has been minutely studied.

Production of Ether. 1. Ether is usually obtained either by distilling a mixture of sulphuric acid and alcohol, or by suffering alcohol gradually to dribble into the heated and somewhat diluted acid. Mr. R. Phillips' directions for the former process are as follows: "Mix with 16 ounces of sulphuric acid, an equal weight of rectified spirit, and distil about 10 fluid ounces; add 8 ounces of spirit to the residuum in the retort, and distil about 9 fluid ounces; or continue the operation until the contents of the retort begin to rise, or the product becomes considerably sulphurous; mix the two products, and if the mixture consist of a light and heavy fluid, separate them: add potash to the lighter, as long as it appears to be dissolved; separate the ether from the solution of potash, and distil about nine-tenths of it, to be preserved as *ether sulphuricus*, the specific gravity of which ought to be at most .750." (*Exptl. Exam. of London Pharmacop.*)

Preparing ether upon a larger scale, it was found that 14 parts of alcohol (specific gravity .820) mixed with an equal weight of sulphuric acid (specific gravity 1.8,) and submitted to distillation, afforded about 8 parts of impure ether (specific gravity .770). 7 parts of alcohol were then added to the residuum, and about $7\frac{3}{4}$ parts more of impure ether drawn off. These products, when mixed, had a specific gravity of about .782, and when rectified by distillation on carbonate of potassa, afforded $10\frac{1}{4}$ parts of ether, of a specific gravity of .735, and about $3\frac{1}{2}$ parts of ethereal spirit, which was employed instead of an equal quantity of alcohol in the next operation.

These processes, when carried on on a small scale, may be conducted in glass retorts with adopters and cooled receivers; but upon the large scale, a leaden still or alembic is most convenient. The ether-apparatus employed at Apothecaries' Hall, consists of a leaden still, heated by means of high-pressure steam carried through it in a contorted leaden pipe; a tube enters the upper part of the still, for the purpose of suffering alcohol gradually to run into the acid in a way which I shall presently explain. The still-head is of pewter, and is connected by about 6 feet of tin pipe, with a very capacious condensing-worm, duly cooled by a current of water; the receivers are of pewter with glass lids, and have a side tube to connect them with the delivering end of the worm-pipe. In conducting this operation, too much caution cannot be observed in avoiding the proximity of fire, and the use of fragile vessels; in all cases in which ether is to be dealt with these cautions cannot be too strictly enforced, as will be more evident when its properties are stated. One of the great advantages in using steam as the source of heat is, that it obviates the necessary vicinity of fire.

2. Boullay's process for the production of ether, which is preferable to the former, is the following: equal parts of sulphuric acid and of alcohol (specific gravity .837) are cautiously mixed in a tubulated retort con-

nected with a tubulated receiver by means of a long adopter; the retort is placed in a sand-heat, and the receiver cooled by the proper application of water. An S tube passes air-tight through the tubulature of the retort, the lower end of which is drawn out into a very small or almost capillary opening, and so adjusted as to dip to about two-thirds of the depth of the liquid in the retort; heat is then applied by the sand-bath till the contents of the retort just begin to appear to boil; the fire is then slackened or damped so as to keep up a regular ebullition, and as the apparatus is air-tight, the expansion within is suffered to escape by a siphon tube, which passes through the tubulature of the receiver. When about 2 pints of product have passed over, an equal quantity of alcohol is so gradually suffered to trickle into the retort by the S tube, as not to check ebullition, but to compensate for that which distils over; when, in this way, a quantity of alcohol has been added equal to that contained in the original mixture, the operation is generally left to itself, and as soon as white vapours, and drops of oil appear in the adopter, the fire is withdrawn. The products of this distillation are usually divided into three parts; the first is alcohol with a little ether, which first passes over; the second and largest portion is mixed with a sixteenth of its weight of carbonate of potassa, which abstracts water and sulphurous acid, and decomposes any oil of wine that may chance to be contained in it; this mixture is shaken, and when the ether has acquired a sweet and pure odour, it is rectified by slow distillation from a water-bath till two-thirds of its original bulk have distilled over; this portion is pure ether. The residue of the rectification is mixed with the last portion of the original distillation, and kept for some days in contact with the carbona of potassa before used, and a little water and peroxide of manganese are added so as to get rid of the sulphurous acid; when this is done, the stratum of ether is drawn off and rectified, but it never equals in quality that of the former part of the process.

It will be observed that, in this process, a large additional quantity of alcohol is gradually added, and converted into ether by the original portion of sulphuric acid; and by obvious contrivances, the same thing may be effected with the still and apparatus used on the large scale.

3. Mitscherlich (in the first volume of his *Lehrbuch der Chemie*) has added some important facts to the preceding details, and has given a form of apparatus for the production of ether which well illustrates it. It consists of a large flask or bolthead, the mouth of which is closed with a cork having three perforations, one of which allows the insertion of a thermometer by which the temperature of the contents of the flask can be regulated; the second admits of the passage of a small tube terminating at its upper end in a funnel, and at its lower, within the flask, in a capillary opening which dips into the liquid; from the third aperture a tube issues for the conveyance of the vapours generated within the flask into a proper condenser immersed in cold water; the end of this tube within the flask is slanted off, so that liquid forming in it may drop back into the flask and not obstruct the free egress of the vapour. Absolute alcohol is first poured into the flask, and then sulphuric acid, somewhat diluted, is gradually added, care being taken to prevent the heating of the mixture above 250° (120 *cent.*) The proportions are 100 parts of sulphuric

acid (which already contains 18.5 of water) diluted with 20 parts of water, and mixed with anhydrous alcohol, in the proportion of 50 parts to every 100 of concentrated acid. To this mixture heat is applied, and it is kept boiling till the thermometer within the flask indicates 284° (140 *cent.*;) two strips of paper are then pasted upon opposite sides of the flask to indicate exactly the bulk of its contents, by showing the level of the liquid within it; alcohol is then suffered to flow in by the funnel-tube, the supply being so regulated as to maintain the boiling-point at 284°. If, having set out with 9 ounces of sulphuric acid, 1$\frac{1}{5}$ oz. of water, and 3 ounces of alcohol in the flask, the specific gravity of each successive 2 ounces that pass over into the receiver attached to the condenser be determined, that of the first 2 ounces will be 0.780, that of the two following 0.788, and this gradually increases to 0.798, at which the density generally arrives by the ninth or tenth ounce, and then remains constant; that being nearly the density of the alcohol used.

If the precaution just stated respecting the adjustment of the temperature be strictly attended to, any quantity of alcohol may be etherized by the same portion of acid, which is no further altered than by foreign matters which may be accidentally present, or by the volatilization of a minute portion along with the ethereal vapour.

The liquid which passes over through the condensing-apparatus into the receiver, separates into two parts, the lighter stratum being ether, with a little alcohol and water; and the heavier, water, with a little alcohol and ether; and when the process has been carefully conducted, the weight of these products exactly corresponds with that of the alcohol consumed. In an experiment in which a large quantity of product had been obtained, it was found to consist of 65 ether, 18 alcohol, 17 water; now the quantity of water which should have been evolved in the production of 65 parts of ether is 15.4; so that the practical is as near to the theoretical result as could be expected, considering the impossibility of preventing the loss of ether by evaporation, and including errors of experiment. Careful manufacturers obtain from 100 parts of spirit of wine, containing 76 parts by weight of anhydrous alcohol, 60 parts of ether of the specific gravity 0.727; according to calculation, they should obtain 58 parts of ether of 0.724. With this diluted alcohol, the water which passes over is of course in greater quantity than when absolute alcohol is used.

The ether of commerce almost always contains alcohol, which materially affects its density; sometimes it also contains water, which is the case with what is termed *washed ether;* and if ether has been long prepared, it is often slightly acid, and leaves a peculiar odour when rubbed upon the hand. In order to procure from it perfectly *pure ether*, it must be well shaken in a close vessel with about twice its bulk of water, and allowed to separate upon its surface; it is then poured off, and a sufficient quantity of well-burned lime added to it, by which the water which it had acquired by the agitation is abstracted; the mixture of ether and lime is then distilled, care being taken to prevent all escape of vapour, and to keep the condensing-receivers cold, and the first third that distils over may be considered as *pure ether*, free from alcohol and from water.

Properties of Ether. Ether is a transparent, colourless, limpid liquid, of a peculiar penetrating and agreeable odour, and a pungent and sweetish taste; it is highly exhilarating, and produces a remarkable species of intoxication when its vapour is respired mixed with air. It is neither acid nor alkaline; it has a high refractive power in regard to light, and is a non-conductor of electricity.

The specific gravity of ether, at 68° is according to Saussure 0.715; according to Gay Lussac its specific gravity (in reference to water at its maximum density) at 90° is 0.69739; at 76° = 0.71192; at 68° = 0.7154; and at 54° = 0.7237. Assuming the water at the same temperature as the ether, its specific gravity at 68° is = 0.71654; and at 58° it is = 0.7240. According to Dumas and Boullay the specific gravity of ether at 68° is = 0.713. This exactly agrees with my own determination of the specific gravity of ether at 60° which had been washed and distilled off quick-lime; this refers to water at 40°.

Ether is eminently volatile*. At mean pressure, it boils according to Gay Lussac at 96°.5. Ether of the specific gravity of .720 may be said to boil, under a pressure of 30 inches, at 98°. Upon this subject, however, the best authorities vary a little, in consequence, perhaps, of variations in the density of the ether and of barometrical pressure, circumstances which easily influence the boiling-point of this liquid; it is also much affected by the nature and cleanliness of the vessel in which the experiment is made. Dr. Bostock found that in a clean glass tube, it might be heated considerably above its boiling-point, but that when in that state a few metal filings or other solid particles were thrown into it, its temperature instantly fell, and it entered into ebullition. (*Ann. of Phil.*, 2nd series, viii. 296.) The extreme volatility of ether renders it impossible to pour it from one vessel to another without losing a portion by evaporation, and its vapour, in consequence of its density, is easily discerned passing off from the liquid; it is this which renders it so dangerous to expose ether near to, and especially above, the flame of a candle. This density of ethereal vapour is well shown by dipping a flock of cotton into ether, and placing it within a glass tube of about an inch diameter, and 18 or 20 inches long; the ethereal vapour will descend and escape from the lower end of the tube, where it may be inflamed by a lighted taper, but none rises to the upper end of the tube. If the lower end of the tube be drawn into a point and bent upwards, the ethereal vapour may there be burned in the manner of a gas-light.

The great *density of ethereal vapour* was first noticed by Dr. Ingenhousz. (*Nouvelles Expériences*, p. 180, as quoted by Dr. Thomson.) Experiments have been made upon this subject by Dalton (*Manchester Mem.:* 2d. series, iii. 260) and by Gay Lussac and Despretz. (*Ann. de Chim. et Phys.*, i. 218, and xxi. 143.) The results of the latter experimentalists closely agree, and place the density of ethereal vapour at mean pressure and temperature, between 2.5808 and 2.5860 in reference to air as = 1.

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* See the experiments at pp. 162 and 168, (figs. 63 and 67) in reference to the low boiling-point, and the cold produced by the evaporation of ether. It is obvious that were it not for atmospheric pressure we should only know ether as a gas or vapour, for in vacuo it boils at all temperatures.

The elastic force of ethereal vapour is shown by letting a drop or two pass up into the vacuum of a barometer, when it instantly depresses the mercury several inches, more or less according to the temperature: hence also, when thrown up into gases standing over mercury, it greatly augments their bulk. The following table shows the result of Mr. Dalton's experiments on the force of ethereal vapour at different temperatures.

Temp.	Force of Ethereal vapour.
36	7.5 inches.
64	15.0
96	30.0
132	60.0
173	120.0
212	208.0
220	240.0

The *volume* of liquid ether is extremely affected by change of temperature; much more so than that of alcohol. The following are the results of Gay Lussac's experiments upon this subject, in which the volume of ether, at its boiling-point, is assumed = 1.000.

Cent.	Fahr.	Bulk.
35.66°	95°	1000.0
30.66	87	991.9
25.66	76	983.8
20.66	69	975.8
15.66	60	968.2
10.66	51	960.9
5.66°	42°	953.6
0.66	33	948.0
− 4.33	26	941.3
− 9.33	14	934.5
−14.33	4	928.0
−19.33	3	922.0

According to Fourcroy and Vauquelin ether congeals or crystallizes when cooled down to −46° (*Ann. de Chim.*, xxix. 289,) but neither Thenard nor Bussy have been able to freeze it, so that the ether used by the former experimentalists was probably impure*.

When ether is inflamed it burns away with a bright and slightly sooty flame, leaving no residue, and producing carbonic acid and water†. By passing ether into a jar supplied with a jet and stop-cock, standing over warm water, its vapour may be burned at the jet: if its vapour be mixed with about 10 volumes of oxygen it explodes by an electric spark, but with smaller quantities of oxygen, or with air, this combustion is only imperfect.

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* From the experiments of Gerard it appears that ether passes more readily through a capillary orifice than water, and water than alcohol; the relative times for equal measures of each fluid at the temperature of 55°, being 101″ for ether, 349″ for water, and 856″ for alcohol. The comparative heights to which these three fluids rose in the same capillary tube were = 6 for ether, 9 for alcohol and 13 for water. (*Ann. de Chim. et Phys.*, vi. 239.)

† When ether is passed over red-hot platinum wire, or consumed in the lamp without flame, an acid is produced, which was first examined by Mr. Daniell, (*Quart. Jour. of Science and Arts*, vi. 318.) He obtained it by placing the lamp, filled with ether and properly trimmed with a coil of glowing platinum wire, under the head of an alembic, in which the vapour was condensed, and collected in a phial applied to its beak. *Lampic acid*, for so he termed this product, is colourless, sour, and pungent; its vapour is very irritating and its sp. gr., when purified, about 1.015. It reddens vegetable blues, and decomposes the alkaline carbonates with effervescence. When added to the solutions of silver, gold, platinum, mercury, and copper, and the mixture heated, the metals are thrown down in the metallic state. On distilling *lampate of mercury*, made by digesting peroxide of mercury in the acid, the lampic acid passes over in the form of a very dense liquid with an intensely suffocating odour. These properties first induced Mr. Daniell to consider this product as a peculiar acid, but, upon further inquiry into its nature and combinations, (*Quart. Jour.*, xii. 64,) he found the acid to be the acetic, combined with a compound of carbon and hydrogen, differing from alcohol and from ether, and conferring upon it those properties, in respect to certain metallic solutions, which have been just mentioned.

Exposed to air and light, as in bottles which are frequently opened, ether becomes less perfectly volatile, and less capable of dissolving fixed oil, in consequence of the formation of a little acetic acid. The presence of this acid is not at first apparent because it forms acetic ether, but it gives the ether a peculiar odour, and in time it becomes acid to tests. (Planche, *Ann. de Chim. et Phys.*, ii. 273). The best way of preserving ether is to keep it in small well-stopped bottles, or even in sealed tubes, and in a dark place. Gay Lussac, in some very old ether, which had been occasionally exposed to air, and the boiling point of which was elevated to 130°, found an oily matter, crystallizable, and of an ethereal odour. According to Döbereiner, ether which has been exposed to air, contains 15 *per cent.* of its volume of nitrogen, the oxygen having combined with the ether.

Ether is soluble to a certain extent, in water, of which nine parts take up one of ether; and washed ether retains about a tenth part of water.

When a little ether is introduced into chlorine, the gas is absorbed and peculiar compounds result, which we shall afterwards examine; when bubbles of chlorine are passed into ether, they often cause inflammation, and when a small quantity of ether is poured into a large jar of gaseous chlorine, previously warmed, it occasionally happens that a considerable explosion ensues. Iodine and bromine are soluble in ether, and gradually react upon and decompose it.

Ether dissolves a small quantity of sulphur, which is not thrown down by the addition of a little water: the solution smells of sulphuretted hydrogen, and by slow evaporation deposits acicular crystals of sulphur. I once had occasion to saturate about a pint of ether with sulphuretted hydrogen gas: the solution was put aside in a well-stopped bottle for some months, and had then deposited small octoëdral crystals of sulphur. Ether dissolves more than 2 *per cent.* of phosphorus; the solution, when concentrated by evaporation, deposits crystals of phosphorus; it is luminous in the dark when in contact of air, and poured upon hot-water produces a brilliant column of luminous vapour. Exposed to air this solution becomes sour; it deposits phosphorus when mixed with water, or with alcohol. It gradually deposits a red matter, especially when exposed to light.

A small quantity of sulphuric acid added to ether produces no effect, but a mixture of equal parts of ether and the acid, blackens, and yields, on distillation, oil of wine, olefiant gas, acetic and sulphurous acid, and water; it leaves a resinous matter and charcoal. Heated with nitric acid ether yields carbonic, acetic, and oxalic acids.

Ammoniacal gas is abundantly absorbed by ether. Potassa and soda act feebly upon it, and give rise, among other products, to acetic acid, which unites to the alkali. Potassium and sodium are slowly converted into potassa and soda, when kept in ether, and hydrogen is disengaged; but the mutual action of these substances has not been accurately studied. The easily oxidable metals, when kept in ether, such as lead, zinc, iron, and tin, are, according to Berzelius, slowly oxidized and form acetates. Many of the salts are also soluble in ether, such as chlorides of gold, platinum, iron, and uranium; the property which ether has of abstracting these salts from their aqueous solutions has been adverted to under the history of the respective metals. The fixed and volatile oils, many of the resins, caoutchouc, various forms of extractive, the alkaloids, and some other vegetable principles are more or less soluble in ether, hence ether is often employed in the proximate analysis of organic products, as a means of separating them from each other.

Alcohol and ether mix in all proportions, and as above stated, the ether of commerce generally contains alcohol, which affects its density and its boiling-point: the means of abstracting the alcohol have been before mentioned. *Hoffman's anodyne liquor*, and the *spirit of ether* of Pharmacy, are such alcoholic solutions.

The following table of the density of various mixtures of ether, (sp. gr. 0.720,) with alcohol (sp. gr. 0.830), is constructed from direct experiments by Mr. Dalton.

Ether.		Alcohol.	Sp. Gr.
100	+	0	0.720
90	+	10	0.732
80	+	20	0.744
70	+	30	0.756
60	+	40	0.768
50	+	50	0.780
40	+	60	0.792
30	+	70	0.804
20	+	80	0.816
10	+	90	0.828
0	+	100	0.830

COMPOSITION OF ETHER. When the vapour of ether is passed through a red-hot tube, it is decomposed with nearly the same phenomena as alcohol, the gaseous products consisting of carburetted hydrogen, carbonic oxide, and a trace of carbonic acid.

Analyzed by passing it through red-hot oxide of copper, ether furnishes the following elementary composition,

				Dumas and Boullay.
Carbon	4	24	64.87	65.0
Hydrogen	5	5	13.51	13.8
Oxygen	1	8	21.62	21.2
Ether	1	37	100.00	100.0

The specific gravity of *ether-vapour* has been shown to be 2.586, and with this, in reference to the above analysis, its calculated density is perfectly consistent, and is as follows:—

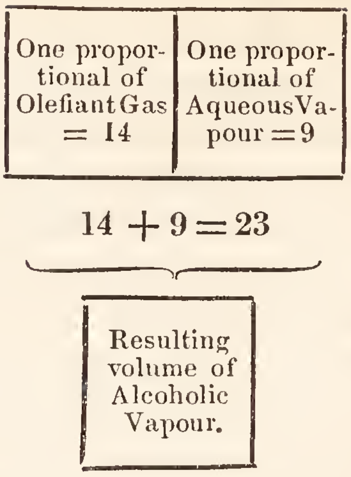
	Volumes.	Sp Gr.
Carbon-vapour	2.	1.687
Hydrogen gas	5.	0.344
Oxygen gas	0.5	0.551
Ether-vapour	1	2.582

These results may be stated, in other terms, as follows:—

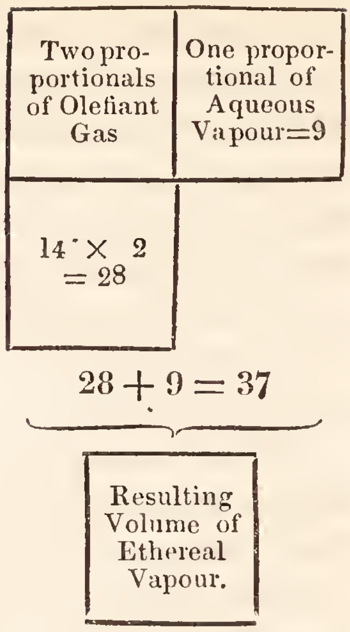
				Vols.	Sp. Gr.
Olefiant gas	2	28	75.6 =	2	1.962
Water	1	9	24.4 =	1	0.620
Ether	1	37	100.0	1	2.582

We thus, therefore, may consider 37 as the *equivalent* of ether; and if we substitute 1 atom of quadrihydrocarbon or *etherine*, for 2 of olefiant gas, ether will then be a *hydrate of etherine*, and the conversion of *alcohol* into *ether* will consist in abstracting from it 1 atom of water: these views are represented in the annexed diagrams, in which both *weights* and *volumes* are evident.

23 parts of Alcohol (by weight) consist of

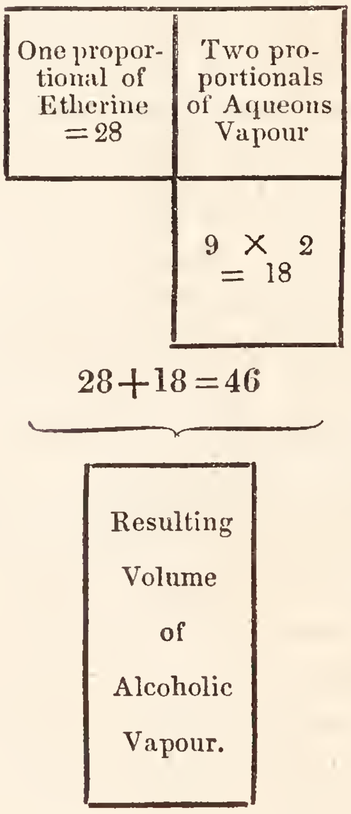

One proportional of Olefiant Gas = 14
One proportional of Aqueous Vapour = 9
14 + 9 = 23
Resulting volume of Alcoholic Vapour.

37 parts of Ether (by weight) consist of

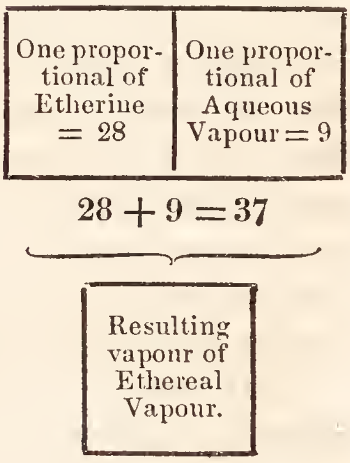

Two proportionals of Olefiant Gas
One proportional of Aqueous Vapour = 9
14 × 2 = 28
28 + 9 = 37
Resulting Volume of Ethereal Vapour.

Or, assuming that view of the composition of alcohol and of ether which represents the former as a *binhydrate*, and the latter as a *hydrate of etherine*, we have

46 parts of Alcohol, composed of


One proportional of Etherine = 28
Two proportionals of Aqueous Vapour
9 × 2 = 18
28 + 18 = 46
Resulting Volume of Alcoholic Vapour.

37 parts of Ether consist of


One proportional of Etherine = 28
One proportional of Aqueous Vapour = 9
28 + 9 = 37
Resulting vapour of Ethereal Vapour.

In either view of the subject, it is obvious that alcohol is convertible into ether, by the removal of one-half of its elementary oxygen and hydrogen, which are in the proportions that form water.

We have therefore the following as the formulæ of ether: $(4\,car+5\,h+o)$, or, $2\,(2\,car+2\,\overline{h)+q}$, or, $(4\,car+4\,\overline{h)+q}$.

Berzelius has adopted another view of these subjects, to which I have elsewhere adverted, and which consists in regarding ether as the oxide of a *compound inflammable basis*, which he terms *ethyle* or *ethule*, (from *ether* and υλη, *principle*,) and which, from reference to the preceding results, will obviously consist of 4 atoms of carbon, and 5 of hydrogen, and be represented therefore by the equivalent 29, (or, $6\times4=24+5$,) and *ether* will contain 29 ethule + 8 oxygen = 37. According to this notion, alcohol is a *hydrate of ether*, consisting of 37 ether + 9 water = 46; hence the necessity of the discordant double equivalent for alcohol, to which I have alluded.

THEORY OF ETHERIFICATION. In the preceding statement respecting the formation of ether, I have purposely avoided adverting to certain intermediate changes which the alcohol undergoes, and which we shall presently proceed to examine, in order to direct attention to the principal and most obvious, or final result, which is, its resolution into ether and water, whilst, at the conclusion of the process, the sulphuric acid remains unchanged. It will be evident, from the details which have been given, that two equivalents of alcohol are converted into one of ether and one of water; or that one volume of the vapour of ether, and one volume of aqueous vapour, are the results of this decomposition of two volumes of alcoholic vapour.

This important fact, namely, that alcohol is converted into ether by the abstraction of water, or its elements, was first clearly demonstrated by Gay Lussac, who at once conceived, that the sole effect and influence of the sulphuric acid consisted in this abstraction of water; and the well-known attraction of that acid for water seemed to sanction the conclusion, which was further strengthened by the fact, that a similar ether might also be formed by the agencies of arsenic, phosphoric, and fluoboric acids, all of which, like the sulphuric, are strongly attractive of water. But in this explanation two circumstances were overlooked, namely, first, that water may be abstracted from alcohol by the alkalis, or by passing it through a red-hot tube, and yet nothing like ether is the result; and, secondly, that water, passes over during the whole of the process along with the ether, with which the acid ought to combine, in reference to decomposing or dehydrating the alcohol.

Mitscherlich considers the formation of ether as a case of *decomposition by contact*, conceiving, that at a certain temperature, (regulated by the dilution of the acid,) alcohol, on merely coming into the contact of sulphuric acid, is resolved into ether and water: he cites the decomposition of oxygenated water, or peroxide of hydrogen, by gold, silver, and peroxide of manganese, and the action of spongy platinum in determining the combination of certain gases, together with the conversion of sugar into alcohol and carbonic acid by the *contact* of ferment, as parallel cases; but if these were parallel cases they still throw no light upon that before us, and the explanation merely substitutes one difficulty for another.

That the mere *abstraction of water* from the alcohol by the sulphuric acid, either in consequence of its affinity, or by contact, is not the sole or efficient cause of the formation of ether, was shown, first by Dabit (*Ann. de Chim.*, xxxiv., 289), afterwards by Sertuerner and Vogel, and subsequently by Hennell. (*Phil. Trans.*, 1826 and 1828.) Sertuerner found that the sulphuric acid underwent more complicated changes; and he called the new acid, which he conceived to result from these changes, *Œnothionic acid*. Vogel afterwards found, that by the action of the alcohol, the sulphuric acid lost much of its power of precipitating the soluble salts of lead; and he called the acid into which it was converted, *Sulphovinic acid*, which term we still retain. Mr. Hennell's experiments prove, that the mutual action of the sulphuric acid and alcohol is *immediate* upon mixture; that its saturating power is diminished; that the new acid forms soluble salts with baryta, and oxide of lead, and other distinct combinations*; he then goes on to show that this acid, the *sulphovinic*, contains sulphuric acid and quadrihydrocarbon, or etherine; and considers it as the agent by which etherine is first formed, and then so evolved, as to unite with water to form ether: in short, that in the conversion of alcohol into ether, the formation of *sulphovinic acid* is an intermediate and a necessary step, and that this acid is a bisulphate of etherine. ($4\,car + 4\,h + 2\,s'$.)

Liebig admits that the formation of sulphovinic acid is an essential step in the process of etherification, but he takes a different view of the nature of that acid, and considers it as a compound of 2 atoms of anhydrous sulphuric acid, 2 of water, and 1 of etherine; or, assuming alcohol to be a *binhydrate of etherine*, and its equivalent 46, he regards sulphovinic acid as a bisulphate of alcohol†. Adopting this theory, we assume that the *formation* of sulphovinic acid is the consequence of the mutual action of alcohol and sulphuric acid upon each other, at a *given temperature*, which temperature is ensured by the state of dilution of the mixture of sulphuric acid, alcohol, and water: if the acid be too dilute, the temperature at which the mixture boils is not high enough to form the sulphovinic acid, and alcohol passes over unchanged; if it be too concentrated the temperature is too high, and the alcohol is decomposed, and olefiant gas is formed; it is between these extremes that the formation of sulphovinic acid ensues; and the mixture most favourable to it, as appears from Mitscherlich's statement (p. 1083), consists of 100 parts of common sulphuric acid, 20 of water, and 50 of anhydrous alcohol.

Now, these proportions are very nearly equivalent to 1 atom of common sulphuric acid, 1 of water, and 2 of alcohol; or, if we double the atom of alcohol, for the convenience of representing it as a *binhydrate of etherine* (see p. 1080), 2 atoms of *anhydrous* sulphuric acid = 80, 2 of water = 18, and 1 of alcohol = 46; now these proportions of sulphuric acid and alcohol are, in themselves, exactly such as would form *sulphovinic acid;* so that we need only suppose them to be subjected to the proper temperature for that purpose; and not only is such *temperature* obtained by Mitscherlich's method of proceeding, but it is kept up during the experiment, and, at the same time, the continuous supply of alcohol furnishes materials for the constant formation of sulphovinic acid; and the sulphovinic acid (consisting of 2 atoms of sulphuric acid, 2 of water, and 1 of alcohol, 23 × 2) is no sooner formed, than it is resolved into sulphuric acid, ether, and water; ether being formed by subtracting 2 atoms of anhydrous sulphuric acid and 1 atom of water from 1 atom of sulphovinic acid.

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* The *immediate change* in the sulphuric acid is rendered evident by the following experiments: 440 grains of sulphuric acid were mixed with an equal weight of alcohol, specific gravity .820; the mixture, when cold, was diluted with water, and saturated by carbonate of soda, of which it required only 398 grains; whereas 440 grains of sulphuric acid saturated 555 grains of the same carbonate: here, therefore, two-sevenths of the acid seem to have been saturated by, or to have entered into some new combination with the alcohol.

440 grains of sulphuric acid were mixed, as before, with its weight of alcohol, and the mixture poured into a solution of acetate of lead; 542 grains of sulphate of lead only were precipitated; whereas the same quantity of sulphuric acid not acted upon by alcohol, threw down 1313 grains of sulphate of lead, so that four-sevenths of the acid had lost its power of precipitating oxide of lead.

Vogel and Gay Lussac have attributed this loss of saturating power to the formation of hyposulphuric acid; and they regard the hyposulphates and sulphovinates as only differing in the latter containing ethereal oil, which in some way acts the part of water of crystallization. But that this is not a correct view of the phenomena will appear from the following experiments on the nature of oil of wine, and of sulphovinic acid.

† We have seen above that *hydrocarbon*, under certain circumstances, performs the part of a *base* (p. 494.) Liebig's view therefore, of sulphovinic acid, represents it as a *hydrated bisulphate of etherine.*

It now only remains briefly to recapitulate the above statements respecting the ultimate and proximate, or theoretical, composition of alcohol and ether, in order to see their mutual bearings; and for this purpose I have represented them in the following table:

ALCOHOL.

	Atoms.	Equivalent Weights			Atoms.	Equivalent Weights.
Carbon	2	12		Carbon	4	24
Hydrogen	3	3	or,	Hydrogen	6	6
Oxygen	1	8		Oxygen	2	16
A Alcohol	1	23		B Alcohol	1	46

	Atoms.	Eqvt. Weights.		Atoms.	Eqvt. Weights.			Atoms.	Eqvt. Wght.		Atoms.	Eqvt. Wght.
Carbon	2	12	Olefiant gas	1	14		Carbon	4	24	Etherine	1	28
Hydrogen	2	2					Hydrogen	4	4			
Do.	1	1	Water	1	9	or,	Do.	2	2	Water	2	18
Oxygen	1	8					Oxygen	2	16			
C Alcohol	1	23		1	23		D Alcohol	1	46	Alcohol	1	46

ETHER.

	Atoms.	Equivalent Weights.
Carbon	4	24
Hydrogen	5	5
Oxygen	1	8
E Ether	1	37

	Atoms.	Equivalent Weights.		Atoms.	Equivalent Weights.		Atoms.	Equivalent. Weights.
Carbon	4	24	Olefiant gas	2	28	Etherine	1	28
Hydrogen	4	4						
Do.	1	1	Water	1	9	Water	1	9
Oxygen	1	8						
F Ether	1	37	Ether	1	37	Ether	1	37

ETHER.						ALCOHOL.					
	Atoms.	Eqvt. Wght.		Atoms.	Eqvt. Wght.		Atoms.	Eqvt. Wght.		Atoms.	Eqvt. Wght.
Carbon	4	24	Ethule	1	29	Carbon	4	24	Ether	1	37
Hydrogen	5	5				Hydrogen	5	5			
						Oxygen	1	8			
Oxygen	1	8	Oxygen	1	8	Do.	1	8	Water	1	9
						Hydrogen	1	1			
G Ether	1	37	Ether	1	37	H Alcohol	1	46	Alcohol	1	46

A and B show the ultimate elements of *alcohol*, in reference to its single and to its double equivalent; C represents alcohol as a *hydrate of olefiant gas* in reference to the equivalent A; and D as a *binhydrate of etherine* in reference to the equivalent B; E shows the ultimate elements and equivalent of *ether*; F represents it as a *dihydrate of olefiant gas*, or as a *hydrate of etherine*; G exhibits ether as an *oxide of ethule*; and H alcohol as a *hydrated oxide of ethule*, or a *hydrate of ether*.

§ XXIII. COMBINATIONS OF ETHER, AND OF ETHERINE OR QUADRIHYDROCARBON, WITH THE OXY-ACIDS.

I. OIL OF WINE; HEAVY OIL OF WINE; SULPHATIC ETHER; SULPHATE OF HYDROCARBON. When the distillation of a mixture of sulphuric acid and alcohol is carried beyond the point at which ether ceases to come over, a portion of a liquid, looking like oil, is obtained, to which the above names have been applied; when washed, it has a bitter aromatic flavour. It has long been known under the name of *oil of wine*, and was formerly regarded as analogous in composition to the volatile oils. In endeavouring to determine the ultimate elements of this oil, by passing it over red-hot oxide of copper, Mr. Hennell always obtained *sulphurous acid*, and a solution of sulphate of copper on washing the oxide he had used, notwithstanding every precaution had been taken to free the oil from all adhering acid. A few drops of the oil were added to a solution of chloride of barium, and gently heated, but no cloud was produced, although litmus-paper indicated the presence of free acid; on evaporating the mixture, however, a precipitate fell as it became concentrated; and, on boiling to dryness, sulphate of baryta was found in the residue. It appeared, therefore, that the sulphuric acid was in some state of combination which prevented its usual action upon tests; or that its elements were in some peculiar state of arrangement in the oil of wine. Mr. Hennell made some experiments to determine the quantity of sulphuric acid thus elicited, from which it appeared, that 100 grains of the oil of wine afforded about 38 grains of *sulphuric acid.* His previous experiments had shown him that *hydrogen* and *carbon* were also elements of oil and wine; and, having determined their proportions by distillation through oxide of copper (adhering moisture and acid having been removed from the oil of wine by quicklime), he obtained from 100 grains (mean of several experiments) 8.30 hydrogen and 53.70 carbon; which appeared to indicate the composition of oil of wine to be 62 *hydrocarbon*, + 38 *sulphuric acid.* It will be observed, that, as respects the carbon and hydrogen, the relative proportions nearly approximate to 6 and 1. Mr. Hennell observes, however, in regard to the above experiments, that we can only infer from them the composition of the *hydrocarbon combined with and neutralizing the sulphuric acid;* for that oil of wine dissolves a variable quantity of hydrocarbon, part of which separates in a crystalline form when the oil is kept for some time, or when exposed to cold. Having thus far determined the composition of oil of wine, its action upon heated solutions of chloride of barium, and chloride of potassium, was more particularly examined; it having been already observed, that in those cases an *acid* is evolved, which does not precipitate baryta. Two hundred grains of oil of wine were gently heated with 6 ounces of water for an hour; precipitated carbonate of baryta was then added, which dissolved, with effervescence, to the amount of 90 grains: the solution, filtered and set to evaporate, became acid, and deposited sulphate of baryta. The experiment, therefore, was repeated; but instead of *evaporating* the barytic solution, it was precipitated by carbonate of potassa, and filtered. The filtered solution, evaporated at a temperature not exceeding 150°, remained *neutral*, and afforded lamellar crystals, greasy to the touch, very soluble in water and alcohol, burning, when heated, with a flame like that of ether, and leaving an acid sulphate of potassa. To determine the composition of the crystals, 20 grains were heated to redness, and left a residue of 10.56 grains of sulphate of potassa, equal to 4.8 sulphuric acid, and 5.76 potassa. 20 grains were dissolved in a solution of caustic potassa, boiled to dryness, heated red-hot, and, when cold, dissolved in distilled water; the excess of potassa was then saturated by nitric acid, and the solution added to one of chloride of barium; 28 grains of sulphate of baryta were obtained, nearly equal to 9.6 of sulphuric acid: the salt, therefore, contained *twice* the quantity of sulphuric acid required to form a neutral salt with the potassa, or *two proportionals.* The remaining elements of the salt were determined by heating it with oxide of copper, from which it appeared that the components of 100 grains are, potassa 28.84, sulphuric acid 48.84, carbon 13.98, hydrogen 2.34, water 7. These numbers may be considered as indicating

1	proportional of	potassa	= 48
2	„	sulphuric acid	= 80
4	„	carbon	= 24
4	„	hydrogen	= 4
			156

Mr. Hennell proceeds to show that the salts obtained from oil of wine are identical with the *sulphovinates* procured from the mixture of sulphuric acid and alcohol; the *sulphovinic acid*, therefore, must be regarded as a compound of two proportionals of sulphuric acid, and one of hydrocarbon, (consisting of 4 proportionals of carbon = 24, and 4 hydrogen = 4;) and corresponding, therefore, to the quadrihydrocarbon or *etherine*, above described. (P. 489.) This acid, however, has the property of neutralizing *single proportionals* only of bases; so that *one* proportional of the sulphuric acid appears to be neutralized by the hydrocarbon, furnishing an analogous instance to the *sulphonaphthalic acid* already mentioned. (P. 493.)

When *sulphovinates* are formed through the medium of *oil of wine*, a portion of quadrihydrocarbon is thrown off, amounting to half that which is contained in the oil; now, as oil of wine is a perfectly neutral compound, it may, in fact, be regarded as a sulphovinate of *etherine*, which in it performs the part of a base; and we may regard it as composed of

Sulphuric acid	2	80		2	80
Carbon	8	48	Etherine	2	56
Hydrogen	8	8			
Oil of wine	1	136	or	1	136

Such is Mr. Hennell's view of the nature of *oil of wine*, and it obviously also includes that of sulphovinic acid, which he considers as a compound of sulphuric acid, with half the above quantity of hydrocarbon, or

Sulphuric acid	2	80		2	80
Carbon	4	24	Etherine	1	28
Hydrogen	4	4			
Sulphovinic acid	1	108		1	108

The part which the sulphovinic acid performs in the generation of ether, I have already explained, and Mr. Hennell has shown, in the papers which I have quoted, not only that *ether* may be obtained from the sulphovinic acid as it exists in the sulphovinates, by combining its hydrocarbon with water, but also that by doubling the water, it yields *alcohol*.

Serullas prepares this oil of wine as follows (*Ann. de Chim. et Phys.*, xxxix., 153.) He distils a mixture of 1 part of alcohol, and 2.5 of concentrated sulphuric acid; a little ether is first formed, then a yellow oil, accompanied by an aqueous acid liquor; the oil is separated, washed in cold water, and then transferred to the receiver of the air-pump, where it is placed by two capsules, the one containing sulphuric acid, the other fragments of potassa; in this way it gradually loses the sulphurous acid, water, alcohol, and ether, with which it was mixed in its original state. It then varies much in colour, becoming green and blue whilst in vacuo, but yellow when exposed to air; it has a penetrating aromatic odour, and a cooling bitterish taste; it is soluble in alcohol and ether, but not in water; its specific gravity is 1.133.

On referring, however, to the analysis of this oil, as given by Serullas, Liebig, and Dumas, it evidently differs in composition from that examined by Hennell; Dumas, indeed, states that it was not obtained twice alike, but he presumes that it contains the true sulphate of hydrocarbon, or *sulphatic ether**, which, he says, should contain

				Dumas.
Sulphuric acid	1	40	52.0	51.6
Carbon	4	24	31.2	31.5
Hydrogen	5	5	6.5	6.8
Oxygen	1	8	10.3	10.1
Heavy oil of wine, sulphate of hydrocarbon, or, sulphatic ether	1	77	100.0	100.0

The other characters of this oil are stated to be as follows: boiled with water, it is gradually converted into sulphovinic acid and alcohol, and an *oily hydrocarbon, lighter than water;* when the boiling is long continued, the whole of the sulphovinic acid is destroyed, and sulphuric acid, alcohol, and the light oil, are the products. Heated with alkaline solutions, the heavy oil of wine is converted into a sulphovinate; and the light oil, and probably alcohol, are given off. Potassium is not acted upon by it without heat, when sulphuret of potassium, and sulphate of potassa are formed.

Light oil of wine, given off from the heavy oil in the above-mentioned processes, has a specific gravity = 0.917 to 0.920; it resembles olive oil. When shaken with water, and exposed in a cold place, it gradually deposits a crystallized substance, which, dried upon blotting-paper, is tasteless, friable, aromatic when heated, specific gravity =.980, fusible at about 230° (110 *cent.*), and volatile at 500° (260° *cent.*)

There can be little doubt that this is the hydrocarbon of oil of wine, above analyzed by Hennell, and which Serullas also found composed of hydrogen and carbon in the ratio of 1 to 6.

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* Dumas observes that it should properly be termed *sulphuric ether*, but to avoid the confusion that would arise in consequence of the application of that term to *ether*, he modifies it as above.

II. Sulphovinic Acid. The composition, production, and some of the properties of this acid have been necessarily included in my account of *ether*, and from the preceding statement, founded on Hennell's researches, it may be represented in its *anhydrous* state, as a compound of 2 atoms of sulphuric acid, and 1 of etherine.

Hydrated sulphovinic acid may be obtained by decomposing *sulphovinate of lead* or of *baryta* by sulphuric acid, or the former by sulphuretted hydrogen; it may be concentrated by the usual process in *vacuo*, taking care to avoid the production of sulphuric acid. In this state it is a colourless, sour liquid, specific gravity = 1.319; it is decomposed by a gentle heat; it dissolves in all proportions in water and alcohol, but is not soluble in ether; chlorine is apparently without action upon it, but nitric acid soon produces sulphuric acid in it; boiled with water, it yields sulphuric acid and alcohol; all its salts are soluble, and most of them easily crystallizable; so that in reference to *hydrated sulphovinic acid* (containing 1 atom of anhydrous acid = 108 + 2 atoms of water = 18) it would appear to be formed by the action of 4 atoms of protohydrated, or common liquid sulphuric acid, upon 2 atoms of alcohol (23 × 2 = 46) in such a way that 2 atoms of anhydrous sulphuric acid unite to the elements of the 2 atoms of alcohol, whilst the remaining 2 atoms of sulphuric acid become bi-hydrated. Thus we have $_4(s' + q) + {}_2({}_2car + {}_3h + o)$ producing $({}_2s' + {}_4car + {}_6h + {}_2o) + {}_2(s' + {}_2q)$. Here again hydrated sulphovinic acid presents itself as a sulphate of alcohol, or as a compound of 2 atoms of sulphuric acid, 1 of quadrihydrocarbon, and 2 of water. These statements are therefore as follows:

Sulphuric acid	2	80	=	1 atom anhydrous sulphovinic acid	108	126
Carbon	4	24		2 atoms water	18	
Hydrogen	6	6				
Oxygen	2	16				
Hydrated sulphovinic acid	1	126				

or

Sulphuric acid	2	80		2	80		2	80
Carbon	4	24	Etherine	1	28	Alcohol	2	46
Hydrogen	4	4						
Do.	2	2	Water	2	18			
Oxygen	2	16						
Hydrated sulphophovinic acid	1	126		1	126		1	126

Sulphovinates. We are indebted for the first accurate analysis of these curious salts to Mr Hennell; they are soluble in water, and many of them in alcohol, by which they are separable from their corresponding sulphates. When heated, they are decomposed with varying phenomena, dependent upon the temperature to which they are submitted, and the nature of the base. At a high temperature, they burn, and leave a carbonaceous residue, containing a bisulphate, or a mixture of a sulphate and sulphuric acid. Only a few of the sulphovinates have been minutely described, but they are an interesting class of salts, and some of them highly deserving further examination: the *sulphovinate of ammonia* especially deserves to be studied.

The *sulphovinates* are generally obtained by heating a mixture of equal weights of alcohol and sulphuric acid, and when cold diluting and saturating it with carbonate of lime, baryta, or lead, when soluble sulphovinates, and insoluble sulphates of those bases are formed, and may be separated by filtration and crystallization. From these salts the other sulphovinates may be obtained, either by double decomposition by the soluble sulphates, or by liberating the sulphovinic acid by sulphuric acid, and then saturating with the required bases.

Sulphovinate of Potassa. (P+*sulv′*.) This salt, which has already been adverted to, forms micaceous crystals, like those of hydrated boracic acid; of a greasy feel and bitter taste. From its composition above given, together with its water of crystallization, it appears to contain,

Potassa	1	48	29.0		1	48
Sulphuric acid	2	80	48.5	Sulphovinic acid	1	108
Etherine	1	28	17.0			
Water	1	9	5.5		1	9
Crystallized sulphovinate of potassa	1	165	100.0		1	165

Sulphovinate of Soda. (S + *sulv′*.) Yields efflorescent crystals of a bitter taste, soluble in 2 of cold and 1 part of boiling water, and containing 1 atom of soda, 1 of sulphovinic acid, and 3 of water.

Sulphovinate of Baryta. (B + *sulv′*.) Forms permanent square tabular crystals, readily soluble in water and insoluble in alcohol, containing,

Baryta	1	77	36.3
Sulphovinic acid	1	108	51.0
Water	3	27	12.7
Crystallized sulphovinate of baryta.	1	212	100.0

When this salt is dried in vacuo, or at a temperature of 164°, it loses 1 atom of its component water.

Sulphovinate of Lime. (C + *sulv′*). By slow evaporation this salt forms quadrilateral tables, very soluble in water and alcohol, and of a slightly sweet taste; and which by desiccation in vacuo lose 2 atoms of their constituent water: when cautiously distilled it yields oil of wine. This salt consists of

					Sulphate of lime	1	68	41.7
Lime	1	28	17.2		Sulphuric acid	1	40	24.5
Sulphovinic acid	1	108	66.2	or	Etherine	1	28	17.3
Water	3	27	16.6		Water	3	27	16.5
Crystallized sulphovinate of lime.	1	163	100.0			1	163	100.0

Sulphovinate of Lead. (Pl + *sulv′*) This salt forms a deliquescent saline mass (Vogel) silky crystals (Dumas) extremely soluble both in water and alcohol.

Sulphovinate of Copper (Cu + *sulv′*) formed by dissolving carbonate of copper in sulphovinic acid, yields large blue tabular crystals, very soluble in water, and soluble in alcohol. It is not precipitated by chloride of barium: when heated a little above 212°, as when long boiled in water, it passes into sulphate of copper. This salt is easily formed by adding sulphate of copper to sulphovinate of baryta. It probably contains 3 atoms of water. (Dumas.)

III. Ethero-sulphuric Acid; Ethionic Acid. $(\dot{E}\text{th} + 2S'.)$ When the vapour of anhydrous sulphuric acid is slowly introduced into absolute alcohol, kept at a low temperature, an oleaginous liquid is formed, and no gas evolved: if too little alcohol has been used, crystals of sulphuric acid form, which redissolve when alcohol is added. The liquid, when mixed with water, does not heat, and on saturating the solution with baryta, abundance of sulphate of baryta is formed, together with a soluble salt of baryta, which must be evaporated in vacuo. This salt contains sulphuric acid, but it is not sulphovinate of baryta, for it is neither soluble in alcohol nor crystallizable; nor does it yield oil of wine when distilled. It contains according to Magnus (*Ann. de Chim. et Phys.*, lii. 155.)

Sulphuric acid	2	80	41.2
Baryta	1	77	39.6
Carbon	4	24	12.4
Hydrogen	4	4	2.6
Water	1	9	4.2
Ethionate of Baryta	1	194	100.0

According to Magnus the acid contained in this salt is constituted of

Sulphuric acid	2	80	68.4
Etherine	1	28	23.9
Water	1	9	7.7
Ethionic acid	1	117	100.0

It is, therefore, a hydrated bisulphate of etherine; whilst sulphovinic acid is an anhydrous bisulphate of etherine; or it is an anhydrous bisulphate of ether. $(2\,S' + 4\,car + 5\,h + O.)$

By partially decomposing ethionic acid by heat, Magnus obtained an isomeric acid which has been termed *isothionic acid:* the salt which it forms with baryta, resembles the ethionate of that base in ultimate composition, but differs from it in its proportion.

According to Dumas, the existence of these distinct acids, namely, the sulphovinic, ethionic, and isothionic, resulting from the mutual action of sulphuric acid and alcohol, was anticipated by Sertuerner, under the terms of *protethionic*, *deutethionic*, and *tritethionic* acids. (*Ann de Chim. et Phys.*, xiii. 62.)

IV. Phosphovinic Acid; Etherophosphoric Acid. It was ascertained many years ago by Boullay, that phosphoric acid might be substituted for sulphuric, in the formation of ether, and Lassaigne found that an acid analogous to the sulphovinic was so formed; the further investigation of this subject has been pursued by Pelouze and by Liebig, (*Ann. de Chim. et Phys.*, lii. 37, and liv. 31.)

Ethero-phosphoric Acid is obtained by the careful decomposition of the etherophosphate of baryta by sulphuric acid, or of the etherophosphate of lead by sulphuretted hydrogen; it is concentrated, first by ordinary evaporation, and then in vacuo. It is then of an oleaginous consistence, colourless, inodorous, very sour, and soluble in water, alcohol, and ether, in all proportions. When much diluted it is not decomposed by continued boiling; but when concentrated, a temperature of 212° gradually resolves it into ether, alcohol, hydrocarbon, and a mixture of phosphoric acid and charcoal. Its concentrated solution affords crystals: it coagulates albumen; and has the same properties whether prepared from phosphoric or from paraphosphoric acid. When diluted, it dissolves zinc with effervescence, and expels carbonic acid from its combinations, forming salts which for the most part are soluble. Pelouze regards this acid as analogous to the sulphovinic in its atomic composition, or as a compound of phosphoric acid and alcohol; but from Liebig's analysis it appears to consist of phosphoric acid etherine and water, and therefore, resembles the ethionic acid.

The crystallized *ethero-phosphate of baryta* includes 12 atoms of water, which may be expelled by heat and the *anhydrous* ethero-phosphate remains; although this salt has been analyzed by Pelouze and Liebig, the results are not satisfactory as relates to the composition of the acid.

V. NITROUS ETHER. HYPONITROUS ETHER. The production of an ethereal fluid by the mutual action of nitric acid and alcohol is said to have been remarked by Paracelsus and afterwards by Kunckel, but it was forgotten till rediscovered by Navier, in 1742. (Navier and Geoffroy, *Mém. de l'Acad. de Paris*, 1742.) It was subsequently studied by Thenard, (*Mém. d Arcueil*, i., 75, and 359,) and more recently by Dumas and Boullay, (*Ann. de Chim. et Phys.*, xxxvii., 19.)

Many processes have been published for the preparation of this ether, (see Dumas, *Ch. App. aux Arts.*, v., 553, and Thomson, *Inorg. Chem.*, ii., 317;) among them, the following, suggested by Thenard, is the least objectionable. Introduce into a sufficiently capacious tubulated retort equal weights of alcohol (specific gravity .820) and of nitric acid of commerce (specific gravity 1.30), and connect it with five Wolfe's bottles, the first of which is empty, and the remaining four half-filled with a saturated solution of salt in water. Apply a gentle heat to the retort, till the liquor begins to effervesce; then withdraw the fire, and the vapour passing through the bottles, which should be kept cold by a mixture of ice and salt, deposits the ether upon the saline solution. In performing this experiment, the retort should not be more than one-sixth filled with the mixture of acid and alcohol; and cold water or other means should be at hand to cool it, if required, in order to subdue the violence of the effervescence. The alcohol should be first poured in, and then the acid, and not mixed by agitation. If the materials are warm, the acid fuming, and the alcohol of proper strength, the action often begins immediately upon mixture, with a cracking noise, escape of air-bubbles, and great effervescence, so that, notwithstanding the size of the retort, its contents are very apt to pass over into the first receiver, and it is often burst; this may generally be prevented by applying a wet cloth to the retort. The tubes through which the vapour is to pass should not be too small, for, in consequence of the suddenness and abundance of its extrication, it requires a ready means of escape: indeed the whole process requires much management and caution, and is most successful when conducted upon rather a small scale in a large retort; with from 3 to 400 grains of alcohol and acid for instance.

When the effervescence has entirely ceased, the residue in the retort is found to be equal in bulk to less than one-third of the materials employed:

the first bottle contains an acid mixture of alcohol, water, and nitrous ether; but the bulk of the ethereal product is found upon the cold saline solution of the second bottle; a little also passes into the third bottle. The ethereal products are collected, digested with powdered lime, and redistilled into a receiver cooled by ice: not more than 100 parts of *rectified ether* are usually obtained from 1000 of the mixture of acid and alcohol.

Besides the ether, many other products are the result of this operation, such as nitrogen and its oxides, nitrous acid, carbonic acid, and traces of acetic acid and acetic ether: oxalic acid sometimes is found in the contents of the retort.

Nitrous ether has the following properties. It has a slightly-yellow tint, and a peculiar odour, which, when much diffused, is not unlike that of ripe apples; its specific gravity 0.880 at 40°. It is extremely volatile, boiling under mean pressure, at a temperature of about 70°, so that at summer-heat it is apt, on removing the stopper of a bottle containing it, to evaporate very rapidly, and even to enter into spontaneous ebullition: dropped upon the hand it instantly disappears and excites great cold; it is very inflammable, burning with a yellowish flame, and leaving no perceptible residue; when recent, it has no action on litmus, but in a few days it becomes perceptibly sour, especially in the presence of moisture and light. Mixed with water, a part is dissolved, and another part decomposed, forming nitric acid, and giving off nitrous gas; mixed with solution of potassa it soon forms hyponitrite of potassa, alcohol, and traces of acetate of potassa. It is without action on ammonia.

There are various modes of viewing the composition of this and similar ethers: as concerns ultimate components, they are as follows:

				Dumas and Boullay.
Carbon . . .	4	24	32.00	32.69
Hydrogen . .	5	5	6.67	6.85
Oxygen . . .	4	32	42.67	41.46
Nitrogen . . .	1	14	18.66	19.00
Nitrous ether .	1	75	100.00	100.00

These elements are equivalent to

Ethule	1	29	38.6	Ether . .	1	37	49.4
Oxygen	1	8	10.8				
Hyponitrous acid	1	38	50.6	. . . . .	1	38	50.6
Nitrous ether . .	1	75	100.0	or	1	75	100.0

Or they may be represented by

Olefiant gas . . .	2	28	37.3	Etherine	1	28
Water	1	9	12.0	Water	1	9
Hyponitrous acid .	1	38	50.7	Hyponitrous acid	1	38
Nitrous ether . .	1	75	100.0	or	1	75

It is obvious from the preceding statement, that this ether may be theoretically regarded either as a *hyponitrite of oxide of ethule* ($eth + o + \underline{\grave{n}}$), or as a *hyponitrite of ether* ($\textsc{Eth} + \underline{\grave{n}}$), or as a *hydrated hyponitrite of etherine*, ($ethn + \underline{\grave{n}} + q$). The composition of the other ethers of this class admits of similar hypothetical representation; the simplest view of the subject is that which regards them as *salts of the oxide of ethule*, or *combinations of ether with the acids*.

VI. Oxalic Ether. This compound was discovered by Bergman (*Opusc. Chim. Phys.*, i.), it was afterwards examined by Thenard, (*Mém. d'Arcueil*, ii. 11.,) and its principal properties shown by Dumas and Boullay in their excellent researches on ethers. (*Ann. de Chim. et Phys.*, xxxvii., and liv.) It is prepared by distilling 1 part of alcohol, 1 of oxalic acid, and 2 of sulphuric acid; alcohol and sulphuric ether pass over, and then an oil-like liquid which collects at the bottom of the receiver, and which is *oxalic ether:* it must be separated from the supernatant liquid, and poured into a glass of water; it often floats at first, but as the sulphuric ether which it contains, gradually evaporates, it falls in drops to the bottom. On adding the alcohol in the receiver, or a fresh portion of alcohol to the residuary contents of the retort, a fresh portion of oxalic ether may be obtained, and this may even be repeated a third time: the different portions of oxalic ether thus obtained are mixed, and purified by boiling with powdered litharge, till its boiling-point attains 360° (183° or 184° *cent.*), when it becomes stationary: performing this operation in a flask with a short neck, the water, sulphuric ether, and alcohol, pass off in vapour, and the excess of acid is retained by the oxide of lead; the oxalic ether is then decanted into a clean dry retort and redistilled.

Oxalic ether, thus prepared, is of specific gravity = 1.0929 at 45°: it boils at 360°, at mean pressure, yielding a vapour of low tension, the density of which is 5.08: its odour is aromatic, with a slight taint of garlic or phosphorus; it is soluble in alcohol and ether, and very sparingly so in water. When dry, it may be long preserved without decomposition; but when humid, it is soon resolved into oxalic acid and alcohol; the hydrated alkalis immediately effect this change, becoming oxalates, and evolving alcohol. It consists of

				Dumas and Boullay.		Vols.	Sp. Gr.
Carbon	6	36	49.31	49.7 =	Carbon vapour	3	2.53
Hydrogen	5	5	6.85	6.5 =	Hydrogen gas	5	0.34
Oxygen	4	32	43.84	43.8 =	Oxygen gas	2	2.22
Oxalic ether	1	73	100.00	100·0 =	Vapour of oxalic ether	1	5.09

Or, it may be represented as

Ether	1	37	50.69 =	Etherine	1	28	38.36
				Water	1	9	12.32
Oxalic acid	1	36	49.31	Oxalic acid	1	36	49.31
Oxalic ether	1	73	100.00	Oxalic ether	1	73	100.00

Hence we have $({}_6car + {}_5h + {}_4o) = (\text{Eth} + ox') =$ oxalic ether. The conversion of this ether into alcohol and oxalic acid by the action of hydrated potassa or soda, depends upon the combination of the ether with an atom of water, at the moment of its evolution; or assuming oxalic ether to be a hydrated oxalate of etherine, it is equally obvious that an additional atom of water would convert the etherine into alcohol.

When a current of dry ammoniacal gas is passed into anhydrous oxalic ether, heat is evolved, and a solid compound is at length formed, which, dissolved in boiling alcohol and filtered, yields silky crystals on cooling. The same compound may be obtained, according to Liebig, (*Ann.*

de Chim. et Phys., liv. 225, and lv. 125,) by mixing oxalic ether with an alcoholic solution of ammonia; the mixture yields crystals, on spontaneous evaporation. To the substance thus obtained, Dumas has applied the name *oxaméthane.* It is colourless, fusible, volatile, soluble in alcohol; soluble in cold water, but converted by boiling into acid oxalate of ammonia. Liquid ammonia immediately converts it into *oxamide.* This substance consists, according to Dumas, of 1 atom of oxalic ether, and 1 atom of ammonia; so that its ultimate elements are

Carbon . . .	6 . .	36	= Oxalic ether 73	= Oxaméthane 90
Hydrogen . .	5 . .	5		
Oxygen . . .	4 . .	32		
Nitrogen . . .	1 . .	14	= Ammonia . 17	
Hydrogen . .	3 . .	3		

These elements are equivalent to

Carbon	2 . .	12	= Oxamide . . . 44
Hydrogen . . .	2 . .	2	
Oxygen	2 . .	16	
Nitrogen . . .	1 . .	14	
Carbon	4 . .	24	= Alcohol . . . 46
Hydrogen . . .	6 . .	6	
Oxygen	2 . .	16	

Hence it is that when aqueous ammonia and oxalic ether are mixed and agitated together, a white precipitate falls, consisting of pure oxamide.

VII. Oxalovinic Acid. When a solution of oxalic ether in anhydrous alcohol is mixed with a similar solution of potassa, in such proportion as to saturate half the acid contained in the ether, crystals are soon deposited, which are almost insoluble in absolute alcohol, and which consist of *oxalovinate of potassa.* This salt is soluble in water, and is not affected by a temperature of 212°; it is anhydrous, and consists of 1 atom of oxalate of potassa, and 1 atom of oxalic ether. It may be decomposed by dissolving it in weak alcohol, filtering the solution to separate a little oxalate of potassa which falls, and then carefully adding sulphuric acid, by which sulphate of potassa is formed and precipitated, and oxalovinic acid set free. It decomposes the carbonates of lime and of baryta, and forms soluble oxalovinates; the pure acid may easily be obtained from the *oxalovinate of baryta.* Many bases, among which is the oxide of copper, decompose this acid, and produce oxalates. When its aqueous solution is evaporated, even with the utmost caution, oxalic acid remains, and the oxalovinic acid disappears. The oxalovinic acid appears to consist of 2 atoms of oxalic acid, and 1 atom of etherine.

VIII. Formic Ether. Distil 7 parts of dry and pulverized *formiate of soda*, with 10 of sulphuric acid, and 6 of anhydrous alcohol; agitate the product, first with a little magnesia to separate acid, and then with water, to abstract alcohol; lastly, deprive it of water and of residuary traces of alcohol by the action of chloride of calcium. (Döbereiner, *Ann. de Chim. et Phys.*, lii., 105.) Formic ether is colourless, and has somewhat of an hydrocyanic odour. Its specific gravity is = 0.915 at 65°. It boils at 132°. It requires 9 parts of water at 65° for solution, and when long boiled with water, especially if potassa be present, it is resolved into alcohol and formic acid. This ether has not been satisfactorily analyzed.

IX. CHLOROCARBONIC ETHER. When absolute alcohol is admitted into a balloon containing chlorocarbonic acid gas, it becomes warm and yellowish; when the action has terminated, air is admitted, and soon after, the liquid may be poured out and mixed with about its volume of distilled water; two layers are presently formed, the one of an oil-like liquid, the other lighter, and containing free muriatic acid. The oily liquor, abstracted by a pipette, and rectified over chloride of calcium and litharge, in a water-bath, has the following properties. It is a colourless liquid, without action on litmus; its odour is peculiar and irritating; it boils at about 200°; its specific gravity = 1.133 at 60°. It consists of

Carbon	6	. .	36	. .	33.0
Hydrogen . . .	5	. .	5	. .	4.6
Oxygen	4	. .	32	. .	29.4
Chlorine	1	. .	36	. .	33.0
Chlorocarbonic ether .	1	. .	109	. .	100.0

Dumas, from whom I have made the preceding abstract (*Chim. App. aux Arts*, v., 570; *Ann. de Chim. et Phys.*, liv., 225,) considers this ether as including a new acid. When it is mixed with liquid ammonia, violent action ensues, muriate of ammonia is formed, and a new product, called by Dumas, *uréthane*, is formed; it is obtained by evaporating the mixture in vacuo to dryness, and distilling it in a dry retort heated by an oil-bath; a colourless liquid, passes over, which concretes into a white crystalline matter, like spermaceti, and sal-ammoniac remains in the retort.

Urethan is white, fusible, and volatile when dry, without decomposition; but, when moist, ammonia is plentifully evolved; it is readily soluble in water and in alcohol, and the solution is neutral. It consists of

					Dumas.
Carbon	6	. .	36	. .	41.0
Hydrogen	7	. .	7	. .	7.3
Oxygen	4	. .	32	. .	36.0
Nitrogen	1	. .	14	. .	15.7
Urethan	1	. .	89	. .	100.0

These elements are equivalent to 2 atoms of carbonic acid $2\,(car + 2\,o)$ 1 atom of ammonia $(n + 3\,h)$ and 1 of etherine $(4\,car + 4\,h)$. There are various other views which may be taken of it, and among them, it may be regarded as consisting of 1 atom of *carbonic ether*, or hydrated carbonate of etherine $= (4\,car + 4\,h) + (car + 2\,o + q)$ and 1 atom of *urea* $= (car + 2\,h + o + n)$. This formula has led Dumas to the term *urethan*.

X. ACETIC ETHER. (ETH $+ ac'$.) This ether was discovered as far back as 1759 by the Count de Lauraguais. It may be prepared by distilling a mixture of 63 parts of concentrated acetic acid, and 17 of sulphuric acid, with 100 of alcohol; the receiver should be carefully cooled; 125 parts may be distilled over. Another process consists in distilling 3 parts of acetate of potassa, 3 of absolute alcohol, and 2 of sulphuric acid, to dryness. The product is mixed with a fifth part of sulphuric acid, and by careful distillation, acetic ether equal in volume to the alcohol may be obtained. The acetic ether, as it is called, of these operations, contains free acid, and alcohol; the former may be abstracted by lime or chalk, and the latter by chloride of calcium.

Acetic ether boils at 105°; it is lighter than water, and has a peculiarly agreeable odour; it burns with a yellowish flame, and acetic acid is developed by its combustion. Water dissolves about one-seventh of its weight of this ether, and the solution is decomposed by potassa, giving rise to an acetate and to alcohol. Ammonia has no action upon it. Acetic ether is composed of

Carbon	8	48	54.55	54.820
Hydrogen	8	8	9.09	8.755
Oxygen	4	32	36.36	36.425
Acetic ether	1	88	100.00	100.000

These elements are equivalent to

Etherine	1	28	31.8	Ether	1	37	42
Water	1	9	10.2				
Acetic acid	1	51	58.0	Acetic acid	1	51	58
Acetic ether	1	88	100.0		1	88	100

The density of the vapour of acetic ether is 3.06, which corresponds with

	Vols.	Sp. Gr.
Carbon vapour	2	1.66
Hydrogen gas	4	0.24
Oxygen gas	1	1.11
Vapour of acetic ether	1	3.01

According to Pelouze, when carbonic acid is passed through an alcoholic solution of acetate of potassa, acetic ether and bicarbonate of potassa are formed; this is a curious instance of etherification at common temperatures; the insolubility of the bicarbonate in alcohol is probably concerned in the action.

Acetal. When alcohol contained in a saucer is covered by an open jar, and some moistened spongy platinum placed in watch-glasses just above its surface, acid vapour is formed, which is absorbed by, or falls into, the alcohol, and gradually renders it very sour; if it be then distilled off powdered chalk, and rectified over chloride of calcium, *acetal* (or *oxidized ether* of Döbereiner) is obtained. It is a colourless fluid, the odour of which resembles that of nitrous ether. Its specific gravity is 0.842. It boils at 167°. It dissolves in alcohol and ether, and in about 6 parts of water. It burns with a bright flame. By potassa, and by sulphuric acid, it is converted into a yellow resin. By the action of spongy platinum it forms acetic acid. (Liebig. *Pogg. Ann.*, xxvii., 605.) It appears to consist of

				Dumas.
Carbon	8	48	59.25	59.7
Hydrogen	9	9	11.13	11.3
Oxygen	3	24	29.62	29.0
Acetal	1	81	100.00	100.0

XI. BENZOIC ETHER. (ETH + *ben.*) Was discovered by Scheele; it may be obtained by subjecting a mixture of 4 parts of alcohol, 2 of benzoic acid, and 1 of muriatic acid to distillation; when about half has passed over, it is returned into the retort, and the distillation is repeated in the same way two or three times. The *ether* is chiefly contained in the residue; it is washed with water, and then carefully distilled off finely powdered protoxide of lead. (Thenard. *Mém. d'Arcueil*, ii., 8.) Its specific gravity is 1.0539 at 50°; its boiling-point 408° = 209° *cent.*; its tension very feeble.

A curious case of the production of this ether has been noticed by Wöhler and Liebig (*Ann. de Chim. et Phys.*, li., 299.) When chloride of benzule and alcohol are mixed, the temperature of the mixture rises so as to produce ebullition, muriatic acid is evolved, and on adding water to the residue, an oil-like substance separates, which is benzoic ether.

Benzoic ether consists of

				Dumas.
Carbon	18	108	72.0	72.40
Hydrogen	10	10	6.7	6.57
Oxygen	4	32	21.3	21.03
Benzoic ether	1	150	100.0	100.00

These elements are equivalent to 1 atom of ether + 1 atom of benzoic acid.

XII. Succinic Ether. (Eth + *suc*′.) Dumas, upon the authority of F. D'Arcet, gives the following process for preparing this ether. Distil together 10 parts of succinic acid, 20 of alcohol, and 5 of concentrated muriatic acid, cohobating the distilled product four or five times; the residue in the retort will then consist of alcohol, water, succinic and muriatic acid, and succinic ether; when mixed with water, the succinic ether separates like heavy oily drops; it is collected, washed with cold water, boiled in a flask with a short neck, till its boiling-point becomes constant, and lastly, distilled off dry protoxide of lead.

Succinic ether is a limpid, colourless, oily liquid, of an aromatic odour; it boils at 417° (214° *cent.*); its specific gravity is 1.036. It is resolved by potassa into succinic acid and alcohol. Chlorine decomposes it under the influence of light, and forms crystals which have not been examined. This ether consists of 1 atom of ether + 1 of succinic acid, or of

Carbon	8	48	55.1
Hydrogen	7	7	8.1
Oxygen	4	32	36.8
Succinic ether	1	87	100.0

XIII. Tartaric Ether. May be obtained from 5 parts of tartaric acid, 7 of alcohol, 2 of sulphuric acid; distil the mixture till a little sulphuric ether begins to be formed. If at this period we withdraw the heat, the liquor assumes a syrupy consistence; but water does not separate the compound of the vegetable acid and alcohol. By adding, by degrees, solution of potassa, we throw down bitartrate of potassa; then, after having just saturated the redundant acid, if we evaporate the liquid, and treat it in the cold with very pure alcohol, we obtain, by evaporation of the alcoholic solution, a substance which, on cooling, becomes like syrup. This substance has a brown colour, and a bitter and nauseous taste. It is void of smell and acidity, and is soluble in water and alcohol. It does not precipitate muriate of lime, but copiously the muriate of baryta. When heated it diffuses dense fumes, which have the odour of garlic, and at the same time it leaves a residue, not alkaline, containing much sulphate of potassa. If distilled with potassa, it is resolved into a very strong alcohol, and much tartrate of potassa. It is, therefore, a combination analogous to the preceding. (*Mém. d'Arcueil*, ii., 13.)

XIV. Citric Ether. When a hot saturated solution of citric acid, mixed with alcohol, muriatic acid, and a certain proportion of sulphuric ether, is kept for 6 or 8 hours at a temperature between 125° and 135°, and then water added, citric ether separates in the form of an oil-like liquid. Its formation in this way is uncertain, and its properties have not been examined. (*Pelouze.*)

§ XXIV. Combinations of Etherine with the Hydracids.

I. Hydrochloric Ether; Muriatic Ether. *Sweet or dulcified spirit of salt*, was a favourite preparation with the alchymists; they conceived it to possess some peculiar solvent powers in regard to salts of gold: it was also used in medicine: it was prepared in various ways; either by distilling a mixture of alcohol and muriatic acid; or of salt, sulphuric acid, and alcohol.

Hydrochloric ether may be obtained by subjecting to careful distillation, a concentrated solution of muriatic-acid-gas in alcohol; or a mixture of 1 part of alcohol, 1 of sulphuric acid, and 2 of fused and finely-powdered chloride of sodium; or a mixture of chloride of antimony, or of tin and alcohol. In all these cases, muriatic ether passes over; it should first be transmitted into warm water, by which its adhering acid and alcohol are abstracted, and its vapour may then be condensed by conducting it through a cold tube, and receiving it in a bottle surrounded by ice and salt.

Muriatic ether, thus condensed, is a limpid, colourless liquid, of a peculiar penetrating odour, and a sweetish flavour: it is neutral: its specific gravity = 0.874 at 42°: it has not been congealed: it boils at about 60°: the specific gravity of its vapour is 2.219. It burns with a flame tinged with green, and exhales the fumes of muriatic acid. Mixed with 4 volumes of oxygen and detonated by the electric spark, it yields 2 volumes of carbonic acid: it is very slowly altered by water and by alkalis. Passed through a red-hot tube, it is decomposed into muriatic acid, hydrocarbon, charcoal, and hydrogen. It consists of $(4\,car + 5\,h + c)$ or $(4\,car + 4\,h + hc')$; or

				Dumas.
Carbon	4	24	36.9	37.73
Hydrogen	5	5	7.7	7.70
Chlorine	1	36	55.4	54.57
Hydrochloric ether	1	65	100.0	100.00

These elements are equivalent to

Etherine	1	28	43.1
Muriatic acid	1	37	56.9
Hydrochloric ether	1	65	100.0

II. Chloral. The mutual action of *chlorine* and alcohol was originally inquired into by Scheele and Westrumb; it afterwards engaged the attention of the principal chemists who have expounded the theory of etherification, and has been more recently investigated by Liebig and by Dumas. (*Ann. de Chim. et Phys.*, xlix., 146; lvi., 113.) The resulting product was originally termed *heavy muriatic ether;* the term *chloral* (referring to chlorine and alcohol), has been applied to it by the last-mentioned chemists. Chloral is obtained by passing a large quantity of chlorine, carefully dried, through anhydrous alcohol; the alcohol is at first kept cold, but when the first action is over, it requires to be gradually warmed; during the whole operation, which lasts several hours, muriatic acid gas is evolved, and must be allowed to escape. Liebig found that several days were required to complete this action upon a quantity of alcohol, amounting to about eight ounces. The product of this operation is mixed with twice its bulk of sulphuric acid, and subjected to careful distillation; a limpid oil-like liquid passes over, which is to be heated in an open flask till its boiling-point attains about 200°; it should then again be distilled off sulphuric acid, and finally rectified off a small quantity of fresh quick-lime, the distillation being performed in a bath of salt and water.

Chloral is a transparent colourless liquid, of a greasy aspect; its specific gravity at 65° is 1.502, its boiling point = 206°: and the density of its vapour about = 5.0. It has an irritating odour, is almost tasteless, somewhat caustic in its action upon the skin, soluble in water, neutral, and its solution is not affected by nitrate of silver. If, instead of dropping the chloral into water, and heating it to effect the solution, it be put into the contact of a few drops of water, the liquids combine into a white crystalline solid, and heat is evolved; and when a few drops of chloral are put into a flask containing humid air, small groups of crystals gradually form upon its interior: these are *hydrate of chloral.* When chloral is poured upon sulphuric acid, and left to itself, it forms a white substance, which Liebig calls *insoluble chloral.* Chloral dissolves iodine, bromine, sulphur, and phosphorus. When its vapour is passed over heated lime or baryta, those bases become incandescent, carbonic oxide is evolved, and metallic chlorides mixed with carbon remain. This sometimes happens in rectifying chloral over quicklime. The hydrated alkaline oxides decompose chloral; nitric acid is almost without action upon it. Chloral consists of

				Dumas.
Carbon	4	24	16.10	16.6
Hydrogen	1	1	0.67	0.7
Oxygen	2	16	10.73	10.8
Chlorine	3	108	72.50	71.9
Chloral	1	149	100.00	100.0

Hydrate of chloral consists of 1 atom of chloral and 1 of water.

I must refer to Dumas (*Chim. app. aux Arts*, v., 608,) for details of the theory of the various changes which alcohol undergoes during the action of chlorine, and the formation of chloral. The term *chloric ether* is sometimes applied to chloral, and sometimes to the chloride of hydrocarbon, described at p. 485.

Chloroform. Soubeiran and Liebig, by distilling chloral mixed with lime and water, or with solution of potassa, obtained a liquid, which when shaken with sulphuric acid, and then separated, and rectified over baryta, in a perfectly-dry retort, yielded a dense limpid fluid, which has been designated *chloroforme.* The same compound is obtained, more easily, by distilling a mixture of 1 pound of chloride of lime, 3 of water, and 3 ounces of alcohol, in a capacious retort; about 3 ounces of chloroforme pass over.

The specific gravity of chloroforme is 1.480 at 65°: its boiling-point about 140°: the density of its vapour = 4.2. It is decomposed when passed over red-hot iron and copper, and, when passed through a red-hot glass tube, deposits crystals, apparently of chloride of carbon. Chloroforme consists of

				Dumas.
Carbon	2	12	9.9	10.24
Hydrogen	1	1	0.9	0.83
Chlorine	3	108	89.2	88.93
Chloroforme	1	121	100.0	100.00

III. HYDRIODIC ETHER. $({}_4\,car + {}_4\,h + hi'.)$ This compound was discovered by Gay Lussac. (*Ann. de Chim. et Phys.*, ix., 89.) It is best obtained by mixing in a retort, 4 parts of iodine, 10 of alcohol of 0.833, and gradually adding 2.5 of phosphorus: when the greater part has distilled over, 3 parts more of alcohol are put into the retort, and the distillation carried to dryness; the product is washed with cold water, and the ether rectified over chloride of calcium.

Hydriodic ether is colourless; it has a penetrating ethereal odour; its specific gravity at 74° is 1.92. It boils at 148°, and the density of its vapour is 5.409. It is not inflammable, but when dropped on red-hot charcoal it diffuses purple vapour. It is decomposed when passed through a red-hot tube, and among the products is an unctuous matter containing iodine. Exposed to air, hydriodic ether becomes red. It is sparingly soluble in water, but readily so in alcohol. Potassium does not decompose it; alkalis, nitric acid, and chlorine, only slowly act upon it; sulphuric acid rapidly decomposes it. It consists of

Carbon	4	24	15.60
Hydrogen	5	5	3.15
Iodine	1	125	81.25
Hydriodic ether	1	154	100.00

or, of 1 atom of etherine + 1 hydriodic acid.

Iodoforme is a compound analogous to *chloroforme*, and obtained by a similar process; its formula is $({}_2\,car + h + {}_3\,i.)$ (Serullas and Dumas., *Ann. de Chim. et Phys.*, lvi., 133.)

IV. HYDROBROMIC ETHER. $({}_4\,car + {}_4\,h + hb'.)$ To prepare this ether, introduce into a tubulated retort 40 parts of alcohol, sp. gr. = .827, and 1 of phosphorus, then add, gradually and carefully, 7 to 8 parts of bromine. The bromide of phosphorus which is formed, decomposes the water of the alcohol, and produces hydrobromic and phosphorous acids: distil by a gentle heat into a cooled receiver. When the distilled product is mixed with water, hydrobromic ether separates and falls to the bottom; if acid, it must be washed with a dilute solution of potassa.

Hydrobromic ether is colourless, transparent, heavier than water, of a strong ethereal odour, and a pungent taste; it is very volatile, soluble in alcohol, and precipitated by water; it has not been analyzed, but probably, like its associates, consists of 1 atom of etherine + 1 hydrobromic acid.

Bromide of lime, distilled with water and alcohol, yields a product analogous to chloroform, which has been termed *bromoform.* (Dumas, *Ann. de Chim. et Phys.*, lvi., 113.)

V. Hydrocyanic Ether. When equal parts of cyanuret of potassium and sulphovinate of baryta are heated in a retort, a product is obtained, which, when washed with water, agitated with, and then distilled off powdered chloride of calcium, yields *hydrocyanic ether.* (Pelouze, *Jour. de Phar.*, xx.) In this operation, the water contained in the sulphovinate is decomposed, its oxygen is transferred to the potassium of the cyanuret, and its hydrogen to the cyanogen to produce *hydrocyanic acid*, which, with the *hydrocarbon* of the sulphovinate, forms this ether.

Hydrocyanic ether is colourless and has a strong alliaceous odour; its specific gravity is 0.70, it boils at 180°. When pure it does not affect a solution of nitrate of silver, and it is with difficulty decomposed by solution of potassa. It dissolves in all proportions in alcohol and in ether. It is sparingly soluble in water. It consists of

Carbon	6	36	65.5
Hydrogen	5	5	9.1
Nitrogen	1	14	25.4
Hydrocyanic ether	1	55	100.0

This ether is poisonous, but much less so than hydrocyanic acid.

VI. Sulphocyanic Ether. By distilling a mixture of 1 part of sulphocyanuret of potassium, 2 of sulphuric acid, and 3 of anhydrous alcohol, Liebig obtained a compound consisting apparently of sulphuret of cyanogen and etherine. (*Ann. de Chim. et Phys.*, xli. 202.)

VII. Hydrosulphuric Ether; Hydrosulphate of Hydrocarbon; Mercaptan; (Zeise, *Ann. de Chim. et Phys.*, xxxv. 87.)

When sulphovinate of baryta is distilled with a concentrated solution of sulphuret of barium, an ethereal liquid passes over, whilst the sulphovinate becomes a sulphate; this liquid floats upon the water; it is to be washed and digested upon powdered chloride of calcium. It is then colourless, combustible, and has an odour resembling assafœtida. It is separable by careful distillation into two compounds; the most volatile, hitherto little examined, has been termed *thiolic ether* (from θειον, *sulphur*,) and the other *mercaptan*, (from *mercurio aptum*), in consequence of its high attraction for mercury. Dumas regards the latter as a *binhydrosulphate of hydrocarbon.* This compound is best obtained by decomposing the *mercaptide of mercury* by sulphuretted hydrogen.

Mercaptan is a colourless liquid, of an extremely penetrating alliaceous odour, and a peculiar sweetish taste; its specific gravity is 0.842 at 60°; its boiling-point about 144°. It does not congeal at – 8°, nor does it redden litmus; it dissolves in all proportions in alcohol and ether, and is sparingly soluble in water. Its alcoholic and aqueous solutions occasion copious lemon-coloured precipitates in solution of acetate, but not of nitrate of lead. It acts powerfully on peroxide of mercury, water is generated, and a colourless crystalline compound peculiarly constituted, is the result. In the same way, it decomposes the perchloride of mercury, forming the same product, with the formation of muriatic acid. This crystalline compound, when subjected to the action of sulphuretted hydrogen, gives rise to the reproduction of the original ether, or mercaptan, and to bisulphuret of mercury, and nothing else. It consists, according to Zeise, of

Carbon	4	24	38.7
Hydrogen	6	6	9.7
Sulphur	2	32	51.6
Mercaptan	1	62	100.0

Now it is obvious that these elements may be regarded as constituting a true ether, or ethereal salt, composed of 1 atom of etherine $= (4\,car + 4\,h)$ + 2 atoms of sulphuretted hydrogen $2\,(s + h)$ so that it corresponds with the other hydracid-ethers, except that it contains 2 atoms, instead of 1, of sulphuretted hydrogen, or hydrosulphuric acid.

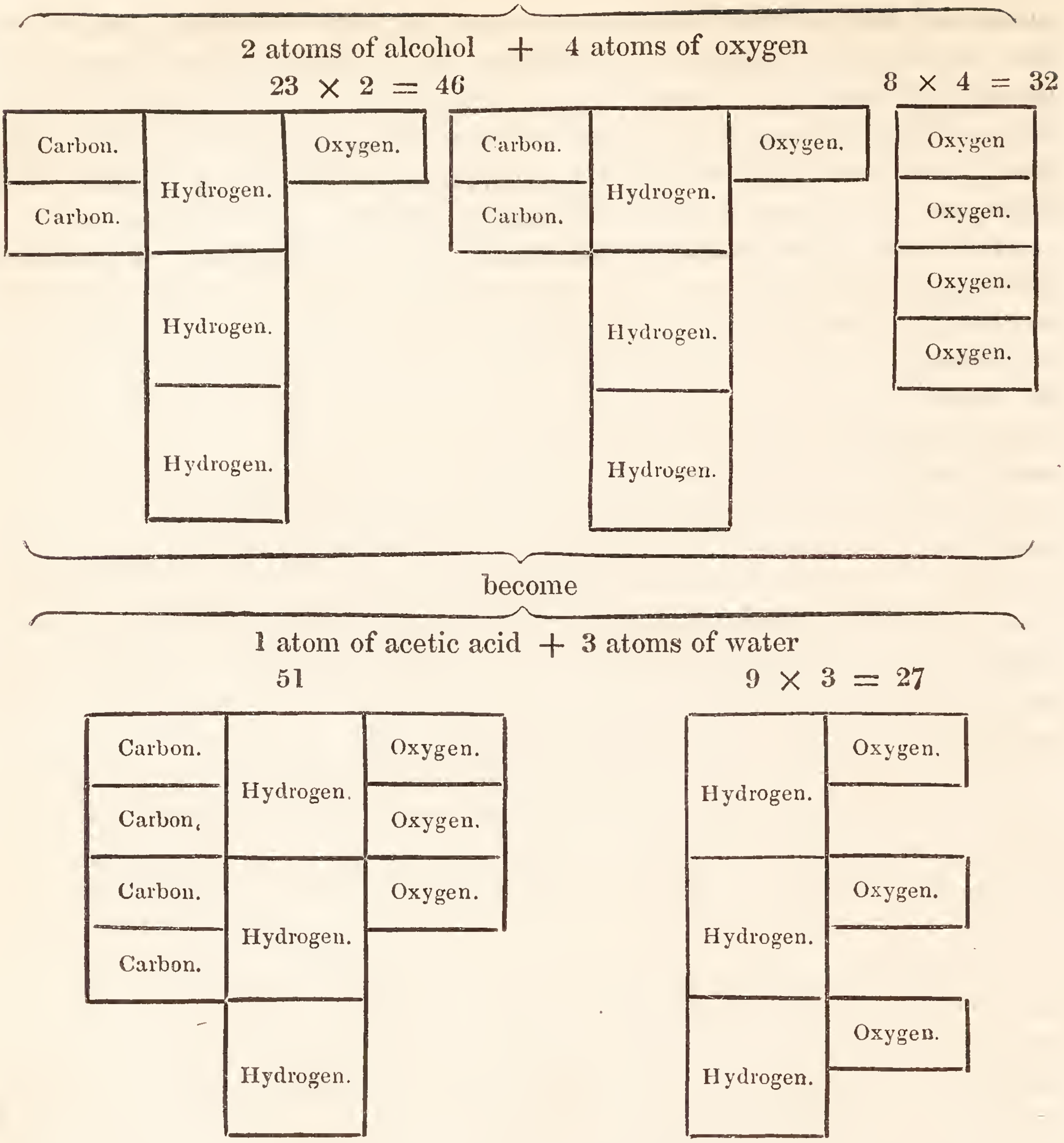
But Zeise regards mercaptan as the *hydruret* of a compound base, which he terms *mercaptum;* this base, therefore, is presumed to consist of $(4\,car + 5\,h + 2\,s.)$ When mercaptan is acted on by potassium, hydrogen is evolved, and a *mercapturet* or *mercaptide of potassium* is formed. So that mercaptan and mercaptum, bear a relation to each other and to other bodies, analogous to cyanogen and hydrocyanic acid.

§ XXV. Acetous Fermentation. Vinegar. Acetic Acid. Pyroxylic Spirit. Lactic Acid.

When any spirituous or vinous liquor, such as wine, or beer, in which vinous fermentation has ceased, is exposed to the access of air, and to a due temperature (above 65°) a new fermentation ensues, in which oxygen is absorbed, carbonic acid evolved, and the alcohol gradually passes into *acetic acid*, which is composed of

				Prout.	Berzelius.	Gay Lussac and Thenard.
Carbon	4	24	47.06	47.05	46.83	50.224
Hydrogen	3	3	5.88	5.88	6.35	5.629
Oxygen	3	24	47.06	47.07	46.82	44.147
Acetic acid	1	51	100.00	100.00	100.00	100.000

It will be recollected that *alcohol* consists of $(2\,car + 3\,h + o.)$ When, therefore, 1 atom of alcohol has the whole of its hydrogen abstracted (by the action of the absorbed oxygen from the air) the remaining elements (which are $2\,car + o$), added to another atom of unchanged alcohol $(+\,o)$, produce *acetic acid.* If, therefore, we set out with *two* atoms of alcohol, and abstract half their hydrogen, we shall convert them, with the addition of 1 atom of oxygen, into 1 atom of *acetic acid:* now this abstraction of hydrogen is in some way induced by the presence of the oxygen of the atmosphere, so that the two atoms of alcohol become in fact converted into 1 atom of acetic acid, and 3 atoms of water, as shown in the following diagrams.



It is evident, therefore, that the evolution of *carbonic acid* which attends acetous fermentation, is not essential to the formation of acetic acid, and is probably referable to the decomposition of a portion of undecomposed sugar, or other matter contained in the liquor, which is susceptible of *vinous* fermentation; or that it may in some cases arise from other changes, or from the decomposition of a portion of the acetic acid itself. The quantity of carbonic acid evolved during the change of wine into vinegar is usually small and very variable, and not one of the leading phenomena, as is the case in vinous fermentation*.

A mere mixture of alcohol and water will not undergo acetous fermentation, without the presence of yeast, gluten, or some analogous substance; hence the more perfect wines do not become sour even when exposed to air, because they contain no ferment.

Although in this mode of producing acetic acid, alcohol is its common source; there are other vegetable substances from which it may be obtained, independent of *vinous* fermentation; as from certain mucilaginous and amylaceous solutions containing vegetable albumen; and when once acetic acid is present, it hastens acetic fermentation, hence the necessity of great cleanliness in regard to the casks and vessels used in vinous fermentation, and in the preservation of wine and beer: sour yeast, paste, and similar acetified substances are also great promoters of acetification.

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* The conversion of alcohol into acetic acid independent of the formation of carbonic acid, is said to ensue during the action of the black precipitate, produced by alcohol in sulphate of platinum (p. 831) upon the vapour of alcohol.

VINEGAR. This term is applied to the *dilute acetic acid*, which is chiefly employed for domestic consumption, and which varies extremely in strength, flavour, and composition, according to the sources whence it is obtained. In wine-countries it is procured by exposing weak wines to the access of air at a due temperature, and its strength, flavour, and colour, depend upon the characters of the wine employed. In this country beer-vinegar is sometimes used, or a *wort* is prepared for the purpose, and, in these cases, the product acquires peculiarities dependent upon the foreign matters necessarily present. A good extemporaneous vinegar may be made by dissolving 1 part of sugar in 6 parts of water, and adding 1 of brandy or other strong spirituous liquor, and a little yeast; this mixture is put into a sufficiently large cask, with the bunghole left open, and exposed to a temperature of between 70° or 80°; in a month or six weeks, the clear vinegar may be drawn off.

In all these cases, the principle of acetification is the same, and consists in the formation of alcohol, and its subsequent conversion into acetic acid by the abstraction of hydrogen, as above explained. Air must always, therefore, have access; but the vessels should not be too open, because in that case acid is lost by evaporation, as the temperature is necessarily high. Vinegar is apt to be infested by *flies* (*Musca cellaris*), and by animalcules, commonly termed *eels* (*Vibrio aceti*): these may be destroyed by passing it through a spiral tube immersed in water heated to 212°, or by heating it in a hot-water-bath. When vinegar is exposed to air, it gradually becomes turbid, or *mothery*, losing its acidity, and depositing a slippery gelatinous substance, which, when collected and dried, resembles gum, and is destitute of nitrogen; it does not, therefore, resemble animal mucus, to which it is sometimes compared. The vinegar becomes weak and mouldy as these changes go on, and they are rapid in proportion to its weakness.

The vinegar of commerce is very various as to strength, and before the present method of producing it from *pyroligneous acid*, which I shall immediately describe, was brought into practice, it was generally adulterated with other acids, especially the sulphuric, a fraud detected by the production of a precipitate insoluble in nitric acid, on the addition of acetate of baryta. Vinegar is also sometimes sharpened by muriatic acid, when it gives a precipitate, likewise insoluble in nitric acid, with nitrate of silver. These precipitates require to be tested, in regard to their insolubility in nitric acid, because they are thus distinguished from other combinations of baryta and of oxide of silver, produced by the other acids or substances present in genuine vinegar. Pepper, and other acrid substances, are rendered evident by carefully neutralizing the vinegar with carbonate of soda, when they are detected by their undisguised pungency.

The specific gravity of vinegar depends more upon the foreign matters which it contains than upon its actual strength, so that its value cannot be judged of by that criterion: the density of the best vinegar (commonly called *white-wine* vinegar), is about 1.020 to 1.025. To ascertain the proportion of *real acetic acid* which it contains, it must be cautiously neutralized by carbonate of soda (dry or crystallized), and the quantity of that salt requisite for the purpose indicates the proportion of real acetic acid present, 54 parts of *dry* carbonate of soda being equivalent to 51 of true or anhydrous acetic acid. The equivalent of *carbonate of lime*, which is 50, is so near that of acetic acid, as to furnish a ready mode of ascertaining the value of vinegar or other dilute acetic acid; for this purpose a piece of clean white marble is selected and accurately weighed, it is then suspended by a thread in a proper quantity of the vinegar to be examined, which is occasionally cautiously stirred, so as to mix its parts without chipping the marble; when it is no longer acted on, it is removed, washed, dried, and weighed; its loss is equivalent to the acetic acid. Another mode of ascertaining the strength of vinegar consists in neutralizing it by hydrate of lime; acetate of lime is extremely soluble, so that the quantity of acetate of lime formed and dissolved, is directly as the quantity of acid present, and the *density* of the resulting solution of acetate of lime, is in the same ratio. (See Messrs. J. and P. Taylor on an *Acetometer*. *Quart. Jour.*, vi.) A solution of ammonia, of known strength, blued by litmus, may sometimes conveniently be used as a neutralizing acetometric fluid.

Distilled Vinegar. When vinegar is subjected to careful distillation, the first portion which comes over usually contains a little alcohol; this is followed by dilute acetic acid, which, towards the end of the process, especially if distilled over an open fire, acquires an empyreumatic odour: the residue is brown, very acid, and has a burned flavour. According to Mr. R. Phillips (on the *London Pharmacopœia*, p. 7), when the best English malt-vinegar, of the specific gravity 1.0204, is distilled, the first eighth part which passes over is of the specific gravity 0.99712, so that it contains a little alcohol; a fluid-ounce of it, = 1.8047 cubic inches, dissolves from 4.5 to 5 grains of precipitated carbonate of lime: the next six-eighths have the specific gravity 1.0023, and a fluid-ounce dissolves 8.12 grains of the carbonate; a fluid-ounce of the acid of specific gravity 1.007 dissolves 15 to 16 grains of precipitated carbonate of lime, or 13.8 grains of marble.

Distilled vinegar is colourless, and wants the agreeable fresh flavour and odour of the original vinegar, compared with which it is flat: this arises partly from a trace of alcohol and of acetic ether which it contains, and also from a peculiar organic matter which passes over in distillation, and which distilled vinegar sometimes deposits in the form of a gray sediment; its nature is unknown: when the acid containing it is neutralized by an alkali and slowly evaporated, it communicates a brown tinge, in consequence of the action of the air upon it. If vinegar has been distilled from a copper still, through a pewter worm, it is always more or less contaminated by copper, lead, or tin, and consequently becomes discoloured, when tested by sulphuretted hydrogen, especially after it has been reduced in bulk by evaporation. Earthenware, or even silver condensing-tubes, are therefore used by the wholesale vinegar-distillers; or upon the small scale, glass vessels may be employed; but the use of distilled vinegar is now almost entirely superseded by that of a mixture of pure acetic acid and water, and this mixture, coloured by burned sugar, is pretty generally employed as a substitute for vinegar.

When vinegar is subjected to a low temperature its aqueous part is that which first congeals, and the remaining unfrozen portion is the strongest; in this way vinegar may, to a certain extent, be concentrated.

Pyroligneous Acid. The production of *vinegar* by the destructive distillation of wood, has already been mentioned as one of the numerous discoveries of Glauber[*]. (p. 26.) It is now conducted upon a large scale, for the express purpose of obtaining that acid. For this purpose the following apparatus is used. A series of cast-iron cylinders, about 4 feet diameter, and 6 feet long, are built horizontally in brick-work, so that the flame of one furnace may play round about two cylinders, both ends of which project a little from the brick-work. One of them has a disc of cast iron well fitted and firmly bolted to it, from the centre of which disc an iron tube about 6 inches diameter proceeds, and enters at a right angle the *main* tube of refrigeration. The diameter of this tube may be from 9 to 14 inches, according to the number of cylinders. The other end of the cylinder is called the mouth of the retort. This is closed by a disc of iron, smeared round its edge with clay-lute, and secured in its place by wedges. The charge of wood for such a cylinder is about 8 cwt. The hard woods, oak, ash, birch, and beech, are alone used. Fir does not answer[†]. The heat is kept up during the day-time, and the furnace is allowed to cool during the night. Next morning the mouth is opened, the charcoal removed, and a new charge of wood is introduced. The average produce of crude vinegar, called *pyroligneous acid*, is 35 gallons. It is much contaminated with tar; is of a deep-brown colour; and has a specific

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[*] Berzelius justly observes that this acid was probably known at a much more remote period, and used by the Egyptians in the process of mummification; he quotes the following passage from Pliny in favour of this opinion. (*Hist. Nat.*, lib. xvi., p. 2.) "Pix liquida in Europa e *teda* (*Pinus silvestris*) coquitur, navalibus muniendis, multosque alios ad usus. Lignum ejus concisum, furnis, undique igne extra circundato, fervet; primus sudor, aquæ modo, fluit canali; hoc, in Syria, *cedrum* vocatur, cui tanta est vis, ut in Ægypto, corpora hominum defunctorum, eo perfusa, serventur." See, in reference to this subject, what I have above said respecting *Kreosote*. (p. 985.)

[†] In reference to this subject, it appears from Stoltze's experiments, that the *wood* of all trees, when thoroughly freed from resin and all soluble matters, yield the same quantity of fluid product when similarly distilled, but that the proportion of acetic acid in it is very variable. The following table illustrates this:

100 parts of dry wood yield	Acid Liquor.	1 ounce of which saturates grains of Carbonate of Potassa.	Empyreumatic Oil.	Charcoal.
Birch, (*Betula alba*)	45	55	8.60	24.4
Beech, (*Fagus sylvatica*)	44	54	9.55	24.6
Oak, (*Quercus robur*)	43	50	9.06	26.2
Ash, (*Fraxinus excelsior*)	46.8	44	8.80	22.1
White poplar, (*Populus alba*)	45.8	39	8.05	23.4
Wild plum, (*Prunus padus*)	43.7	37	10.35	21.6
Juniper, (*Juniperus communis*)	45.8	29	10.73	22.7
Spruce fir, (*Pinus abies*)	41.2	29	13.70	21.2
Scotch fir, (*Pinus sylvestris*)	42.4	28	11.80	21.5

gravity of 1.025. Its total weight is therefore about 300 lbs. But the residuary charcoal is found to weigh no more than one-fifth of the wood employed. The crude pyroligneous acid is rectified by a second distillation in a copper still, in the body of which about 20 gallons of viscid tarry matter are left from every 100. It has now become a transparent brown vinegar, having a considerable empyreumatic smell, and a specific gravity of 1.013. Its acid powers are superior to those of the best household vinegar, in the proportion of 3 to 2. (Ure's *Dictionary*, Art. Acid, *acetic.*)

The purification of this crude acid is generally effected as follows; it is saturated with slaked lime, previously made into a thin cream with water; in this way much of the empyreumatic extractive is precipitated in insoluble combination with the lime; the clear solution, containing acetate of lime, is then drawn off and mixed with a concentrated solution of sulphate of soda, till no further precipitation of sulphate of lime ensues; when this has fallen, the supernatant liquor is let off, the residuary sulphate washed, and the whole of the solution evaporated; during this process, empyreumatic resin separates upon the surface, and is skimmed off, and when the solution has acquired a due density, it is set aside to crystallize, and the mother-liquor is poured off and treated as before. At last, a brown uncrystallizable liquid remains, which contains, besides acetate of soda, an empyreumatic extractive, and resin combined with soda, and which may be decomposed by evaporation to dryness, and calcination, so as to leave the soda. The crystallized salt, which is impure acetate of soda, after having been purified by solution and re-crystallization, is fused in an iron pot, stirred till it dries, and the heat is then carefully raised to incipient carbonization, by which the empyreumatic matters which rendered it impure are carbonized, whilst the salt itself, if the operation be skilfully conducted, is little damaged; the mass is then dissolved in water, filtered, and re-crystallized, and yields pure *acetate of soda.* This salt is then distilled with 0.36 of its weight of sulphuric acid, either in glass, or in metallic stills with silver condensers. The product is a strong acid, of the specific gravity 1.05; it still has an empyreumatic flavour, which is removed by well-burned animal charcoal; it is then duly diluted with water, and applicable to all the purposes for which common vinegar is employed; when intended for the table, it is coloured by burned sugar, and flavoured by a few drops of acetic ether. For pickles and sauces of all kinds, it is generally used in a somewhat stronger state than common vinegar. It is used as a substitute for vinegar in all the processes of the arts, being more or less purified in these cases, according to the purposes for which it is required.

Acetic Acid. Pure acetic acid, or as it was formerly called, *radical vinegar*, is obtained by decomposing acetate of soda; this salt is first purified by two or three solutions and crystallizations, and then carefully desiccated, by heating and stirring it, without fusion, in an iron basin; it is then pulverized, and put into a capacious tubulated retort, with two equivalents of pure sulphuric acid, at a temperature of about 125°; acetic acid is liberated, but when about an eighth part has passed over, the retort must be carefully heated; the distillation may be continued till the saline matter in the retort, which is bisulphate of potassa, is in quiet fusion. The products of this first distillation must be rectified over a little dried acetate of soda, then placed in ice till it congeals; the congealed acid is suffered to drain by inverting the bottle which contains it, and in that frozen state it may be regarded as pure hydrated acetic acid; it retains its solid form till the thermometer rises to about 50°; if cooled down to 45°, and then shaken, or a particle of solid matter dropped into it, it congeals, and at the same time an immersed thermometer rises to 51°. Its crystals are generally flat plates of a pearly lustre; it has a strong irritating odour, agreeable when much diluted, and is powerfully acid and caustic, reddening the skin, and raising a blister. It absorbs moisture from the air, and dissolves in all proportions in water and in alcohol. The specific gravity of this acid (the liquefied crystallized acid) is 1.06296 at 60°, (Thomson,) but its density is no criterion of its strength, as shown in the following table, drawn up by Dr. Thomson, according to whom the crystalline or glacial acid consists of 1 atom of anhydrous acid + 1 atom of water.

Atoms of Acid.		Atoms of Water.		Sp. Gr. at 60°.
1	+	1	. .	1.06296
1	+	2	. .	1.07060
1	+	3	. .	1.07084
1	+	4	. .	1.07132
1	+	5	. .	1.06820
1	+	6	. .	1.06708
1	+	7	. .	1.06349
1	+	8	. .	1.05974
1	+	9	. .	1.05794
1	+	10	. .	1.05439

The liquid acid, therefore, is at its greatest density when it consists of 1 atom of anhydrous acid, and 4 atoms of water, or of about 100 of real acid and 72 of water. It appears, also, that the density of the acid containing only 1 atom of water, is nearly the same with that containing 7 atoms.

Acetic acid has not been obtained in an uncombined anhydrous state. When heated, it distils over without change. It is only partially decomposed by a red-heat; but if passed over red-hot charcoal, it yields carbonic acid, water, carbonic oxide, and carburetted hydrogen.

Cold acetic acid is uninflammable, but when heated, its vapour burns with a blue flame; the oxyacids are almost without action upon it. Chlorine, under ordinary circumstances, little affects it, but exposed to it under the direct solar rays, muriatic and chlorocarbonic acids are formed, and a crystalline substance, which Dumas considers as hydrated chloral.

Acetic acid is displaced from its combinations by most other acids. It forms a well-defined class of salts, *acetates*, all of which are soluble in water, and in which the oxygen in the acid is to that in the base as 3 to 1. Some of the peroxides convert part of this acid into carbonic acid and water, by which they are reduced to a soluble state, and form protacetates. It is a solvent of many organic products, among which are camphor, resins, and albumen.

The composition and equivalent of the anhydrous acetic acid have been above given; the crystalline, or hydrated acid $(ac' + q)$ consists of

								Mollerat.
Anhydrous acetic acid .	1	...	51	...	85	...	87.125
Water	1	...	9	...	15	...	12.875
Crystallized acetic acid .	1	...	60	...	100	...	100.000

It will be seen by referring to the atomic constitution of the *anhydrous* *acetic acid*, that it is represented by $({}_{4}car + {}_{3}q)$, or $({}_{4}car + {}_{3}h + {}_{3}o)$, and that the *hydrated* or crystalline acid, represented by the formula $({}_{4}car + {}_{4}q)$ or $({}_{4}car + {}_{4}h + {}_{4}o)$, may be regarded as including equal volumes of hydrogen and carbonic oxide.

The production of acetic acid by the slow combustion of alcohol has been above alluded to; Mitscherlich compares its formation by the exposure of alcohol, water, and a ferment, to air, to that process, and alludes to the mode of forming it sometimes practised, which consists in suffering a mixture of 1 part of alcohol and 8 or 9 of water, with a little yeast, to trickle through beech shavings previously soaked in vinegar, and lying loosely in a cask perforated full of holes; he says that the air loses so much oxygen, that if collected as it issues from the upper holes, it extinguishes flame, and that the temperature of the liquid rises to 85°, when that of the atmosphere is only 60°; that by the first operation, half the alcohol is acetified, and that the acetification is complete by a repetition of the process, provided it be slowly conducted; and that vinegar may be made in this way in a few hours.

CHARACTERS OF THE ACETATES. It has already been stated that these salts are soluble in water; there are, perhaps, two exceptions, in those of molybdenum and of tungsten, and the acetate of silver and of protoxide of mercury are difficultly soluble. The acetates are decomposed by heat, and yield variable products; those of the alkaline bases yield carbonates, carbonic acid, oxide of carbon, a little carburetted hydrogen, a small quantity of water and of oil, and *pyroacetic spirit*, or *acetone*. Some of the acetates yield acetic acid scarcely altered; and some a mixture of acid and spirit, leaving charcoal, and the metal or its oxide. The fusible acetates concrete, on cooling, into foliated masses. When acetates are in dilute aqueous solution, they often suffer spontaneous decomposition; some of them become carbonates, and a green mould forms upon their surface. These salts are recognised by the evolution of acetic acid when acted on by sulphuric acid; and many of them yield a precipitate of nacreous crystalline scales, with a solution of protonitrate of mercury.

ACETATE OF AMMONIA $(A + ac')$ is a very deliquescent, soluble salt, and extremely difficultly crystallizable. In solution, obtained by saturating distilled vinegar with carbonate of ammonia, it constitutes the *liquor ammoniæ acetatis* of the *Pharmacopœia*, which has long been used in medicine as a diaphoretic, under the name of *spirit of Mindererus*. Acetate of ammonia is volatile at 250°, and condenses in crystals. Its theoretical composition is

Ammonia	1	17	25
Acetic acid	1	51	75
Acetate of ammonia . .	1	68	100

ACETATE OF POTASSA $(P + ac')$ is usually formed by saturating distilled vinegar with carbonate of potassa, and evaporating to dryness. If this salt be carefully fused, it concretes into a lamellar deliquescent mass on cooling. It is the *terra foliata tartari*, and *febrifuge salt of Sylvius*, of old pharmacy. It dissolves in its own weight of water at 60°, and the solution has an acrid saline taste. Boiling alcohol dissolves twice its weight. When chlorine is passed through the aqueous solution of this salt, carbonic acid is evolved, and a powerful bleaching-liquid formed;

exposed to air, it gives out chlorine; distilled, it yields acetic acid, a little chlorine, and no oxygen. Carbonic acid decomposes the alcoholic solution of acetate of potassa, carbonate of potassa is deposited, and acetic acid, which produces some acetic ether, is set free. When a mixture of acetate of potassa and of arsenious acid are distilled together, carburetted and arsenuretted hydrogen, carbonic acid, water, pyroacetic spirit, and an oil-like liquor mixed with metallic arsenic are the results (Cadet's fuming liquor); acetate of potassa is anhydrous, and consists of

				Wenzel.	Richter.
Potassa	1	48	48.5	50.15	51.4
Acetic acid	1	51	51.5	49.85	48.6
Acetate of potassa	1	99	100.0	100.00	100.0

Acetate of Soda. ($S + ac'$.) This is an easily-crystallizable salt; its forms are very complex, and are derived from an oblique rhombic prism. (Brooke, *Ann. of Phil.*, 2nd series, vi., 39.) When it contains a little tar, the crystals are often bulky; they effloresce in dry air, are soluble in 3 parts of cold and less of boiling water, and are sparingly soluble in alcohol. This salt has a bitterish, pungent, but not disagreeable flavour; it fuses when heated, and concretes into a lamellar mass, formerly called *terra foliata mineralis.* It is of importance, as above stated, as a source of acetic acid; at a red-heat it leaves a mixture of carbonate of soda and carbon, in a favourable state for the preparation of sodium. The *anhydrous* salt consists of

				Berzelius.	Wenzel.
Soda	1	32	38.5	38.311	39.67
Acetic acid	1	51	61.5	61.689	60.33
Anhydrous acetate of soda	1	83	100.0	100.000	100.00

The crystallized salt ($S + ac' + 6q$) includes 6 atoms of water, or

				Thomson and Berzelius.
Soda	1	32	23.3	22.94
Acetic acid	1	51	37.3	36.95
Water	6	54	39.4	40.11
Crystallized acetate of soda	1	137	100.0	100.00

Acetate of Lithia is a very deliquescent and difficultly-crystallizable salt.

Acetate of Lime ($C + ac'$) forms silky acicular prisms, which effloresce when heated, and are soluble in water and alcohol; this salt is used in the formation of acetate of soda in the process for procuring acetic acid; it is anhydrous, and consists of

				Berzelius.	Higgins.	Richter.
Lime	1	28	35.4	35.4	35.7	34.3
Acetic acid	1	51	64.6	64.6	64.3	65.7
Acetate of lime	1	79	100.0	100.0	100.0	100.0

Acetate of Baryta ($B + ac'$) is formed by digesting sulphuret of barium or carbonate of baryta in acetic acid, filtering and evaporating; dried at 212°, it yields a white powder, soluble in about its weight of water, and sparingly soluble in alcohol, and of an acrid pungent taste: when crystallized at a temperature below 60°, it includes, according to

Mitscherlich, 3 atoms of water, and its form resembles that of acetate of lead; above 60° it forms crystals with 1 atom of water, which are irregular six-sided prisms, terminated by diëdral summits, the primary form of which is a right rhomboidal prism. (Brooke, *Ann. of Phil.*, 2nd series, vii., 365.) In cold weather the concentrated solution concretes into a congeries of silky crystals. It is sometimes used as a test of sulphuric acid. The *anhydrous* salt consists of

				Bucholz.	Richter.
Baryta	1	77	60.1	60.56	59.4
Acetic acid	1	51	39.9	39.44	40.6
Anhydrous acetate of baryta	1	128	100.0	100.00	100.0

and the common *crystallized* acetate contains

				Bucholz.
Baryta	1	77	56.2	56.70
Acetic acid	1	51	37.2	36.93
Water	1	9	6.6	6.37
Crystallized acetate of baryta	1	137	100.0	100.00

Acetate of Strontia (Str + ac') is a very soluble salt, which, when crystallized, includes 2 atoms of water. The crystals formed below 60° contain 4 atoms of water.

Acetate of Magnesia (M + ac') is a very difficultly crystallizable salt; it is generally obtained in the form of a gum-like mass, slightly deliquescent, soluble in water and alcohol, and composed of

				Richter.
Magnesia	1	20	28.17	28.9
Acetic acid	1	51	71.83	71.1
Acetate of magnesia	1	71	100.00	100.0

Acetate of Manganese. (Man + ac'.) This salt is prepared for the use of calico-printers, by mixing sulphate of manganese with acetate of lime. It forms transparent pale-red rhomboidal tables, soluble in water and alcohol.

Protacetate of Iron. (Fe + ac'.) This salt is obtained by the action of acetic acid on protosulphuret of iron: it forms a mass of white silky crystals when evaporated out of contact of air. When iron-filings are digested in acetic acid, the resulting solution contains a mixture of peracetate and protacetate.

Peracetate of Iron may be obtained by digesting turnings and clippings of iron in acetic acid; or by dissolving peroxide of iron in the acid; or by mixing acetate of lead with sulphate of iron: it forms a deep reddish-brown solution, which, when carefully concentrated, yields a gelatinous residue, but does not crystallize; if rapidly evaporated, it deposits a yellow powder, which is said to be a diacetate. This solution is much employed by dyers and calico-printers.

Acetate of Zinc (Zn + ac') is formed either by dissolving oxide of zinc in acetic acid, or by mixing a solution of sulphate of zinc with one of acetate of lead. It crystallizes in thin shining rhomboidal plates, of a bitter and metallic taste, very soluble, but not deliquescent: their primary form is an oblique rhombic prism. (Brooke, *Ann. of Phil.*, 2nd ser., vi., 39.)

This salt is sometimes used in pharmacy, chiefly as an external application. According to Messrs. Aikin, the specific gravity of a saturated solution of acetate of zinc, made by digesting the metal in distilled vinegar, is 1055. Of this solution, 900 grains contain 53 of dry, or 82.6 of crystallized acetate. One ounce, by measure, of the solution, weighs 506 grains, and contains 29.8 grains of dry, or 46.5 grains of crystallized salt. This salt, in its crystallized form, includes, according to Thomson, 7 atoms of water.

Acetate of Tin. This metal is slowly acted on by acetic acid, but a *protacetate* and *peracetate of tin* may be made by mixing acetate of lead with saturated solutions of the protomuriate and permuriate of tin. These solutions have been recommended as mordants for the use of dyers. The protacetate is crystallizable. Vinegar, kept in tin vessels, dissolves a very minute portion of the metal; and in pewter vessels it likewise dissolves a small portion of the lead, where in contact both with the vinegar and air; hence, distilled vinegar, which has been condensed in a pewter worm, affords generally traces of both metals. (Vauquelin, *Ann. de Chim.*, xxxii.)

Acetate of Cadmium. ($\mathrm{Cad} + ac'$.) When a concentrated solution of this salt is exposed for about ten days to the air, it is gradually converted into a crystalline mass, while a dense liquid remains above it. The crystals are prisms, very soluble in water, and not altered by exposure to air: they include 2 atoms of water. (Thomson.)

Acetate of Cobalt. Oxide of cobalt is easily soluble in acetic acid forming a red solution; it yields a red deliquescent salt when carefully evaporated, becoming blue when heated, and forming a good sympathetic ink. (Ilsemann, *Crell's Annals*, 1785, ii., 25.)

Acetate of Nickel. ($\mathrm{Nic} + ac'$.) Carbonate of nickel dissolves readily in acetic acid, forming a dark-green solution, from which rhomboidal crystals may be obtained, soluble in water, but insoluble in alcohol; when heated, they give out water and become yellow, then burn like tinder, and leave oxide of nickel: they include 5 atoms of water.—(Thomson.)

Acetate of Copper. ($\mathrm{Cu} + ac'$.) This salt is generally distinguished as *crystallized verdigris:* it has been long known, and is described by Pliny, (lib. xxxiv., c. ii.) It is prepared by dissolving the *subacetate* or *common verdigris* in acetic acid; the solution is put into pans and allowed slowly to crystallize, generally upon twigs or pieces of string suspended in it: it forms oblique rhombic prisms (Brooke, *Ann. of Phil.*, 2nd series, vi., 39), of a rich blueish-green colour, soluble in 5 parts of boiling water, and sparingly soluble in alcohol. The dilute aqueous solution is decomposed when boiled, and deposits a tribasic salt. When this salt is heated in the air, it burns with a green flame; submitted to destructive distillation, it yields water, acetic acid, pyroacetic spirit, carbonated gases, and a white crystalline sublimate, which is an *acetate of the suboxide of copper;* it leaves a residue of very finely-divided copper mixed with a little charcoal, which burns like tinder when heated, and at a high temperature is pyrophoric. This salt was formerly a principal source of strong acetic acid, but since the discovery of the modes of purifying and concentrating pyroligneous acid, it has fallen into disuse. When sugar is added to a boiling solution of acetate of copper, a red crystalline powder, said to be pure suboxide of copper, falls, and the remaining filtered solution contains some peculiar combination of copper, which has not, I believe, been accurately examined. This salt consists of

			Phillips.	Ure.	Gehlen.	Berzelius.
Oxide of copper . .	1	40	39.2	39.6	40	39.29
Acetic acid	1	51	49.9	52.0	60	60.71
Water	1	9	11.9	8.4		
Crystallized acetate of copper	1	100	100.0	100.0	100	100.00

DIACETATE OF COPPER. SUBACETATE OF COPPER. $(2\,\mathrm{Cu} + ac')$ This dibasic salt is the common *verdigris* of commerce; it is prepared by exposing thin plates of copper to the action of acetic acid, or its fumes; the method now practised consists in alternating plates of copper, with pieces of woollen cloth steeped in acetic acid; they gradually become corroded and superficially covered with verdigris, which is from time to time removed and the operation repeated, as long as the plate lasts. Sometimes the husks and stalks of grapes or raisins, in a state of acetous fermentation, are employed to act upon the copper, as is the case with some of the French verdigris. This article is commonly rolled or packed in white leather, and is frequently much adulterated with a mixture of chalk and sulphate of copper. Pure diacetate of copper is in small silky crystals; when moistened a little it crumbles, and is only partially soluble in water. This salt consists of

				Berzelius.
Oxide of copper . .	2	80	43.24	43.34
Acetic acid	1	51	27.57	27.45
Water	6	54	29.19	29.21
Hydrated diacetate of copper	1	185	100.00	100.00

Mr. Phillips has given the following comparative statement of the composition of the different kinds of verdigris. (*Ann. of Phil.*, second series, vi., 39.)

	Blue Crystals.	French Verdigris.	English Verdigris.
Acetic acid	28.30	29.3	29.62
Peroxide of copper . .	43.25	43.5	42.25
Water	28.45	25.2	27.51
Impurity	0	2.0	0.62
	100.	100.	100.

SUBSESQUIACETATE OF COPPER. $(1\frac{1}{2}\,\mathrm{Cu} + ac')$ This sesquibasic salt is obtained by triturating the diacetate with water, filtering the solution, concentrating it by slow evaporation, heating so as to dissolve the deposit, and then adding alcohol; when the solution is set aside a gelatinous mass of minute crystals is formed, which when dry are of a pale blue colour, and consist of

				Berzelius.
Oxide of copper	1½	60	43.48	43.19
Acetic acid	1	51	36.96	36.80
Water	3	27	19.56	20.01
Hydrated subsesquiacetate of copper	1	138	100.00	100.00

Trisacetate of Copper. ($3\,\mathrm{Cu} + ac'$.) This tribasic salt is the portion of the *diacetate* which is insoluble in water, and which, when thoroughly washed with alcohol, and dried at 212°, consists of

				Berzelius.
Oxide of copper . .	3 . .	120 . .	63.5 . .	64.36
Acetic acid . . .	1 . .	51 . .	27.0 . .	27.60
Water	2 . .	18 . .	9.5 . .	8.04
Hydrated trisacetate of copper . . .	1	189	100.0	100.00

Acetate of Lead. The oxide of lead combines, like the oxide of copper, in several proportions with acetic acid. The *neutral acetate*, ($\mathrm{Pl} + ac'$,) has long been known under the name of *sugar of lead;* it is the *salt of Saturn* of the old chemists, and is a considerable article of commerce, being much used in various operations connected with dyeing and calico-printing. It is now exclusively prepared by digesting oxide of lead in pyroligneous acid, or in pure acetic acid, and is found, in trade, of various degrees of purity, according to the purposes for which it is intended. When plates of lead are exposed to the fumes of vinegar or acetic acid, they become corroded and incrusted with a white powder, which is carbonate of lead (p. 718), and which, scraped off and dissolved in excess of acetic acid, forms a solution from which crystallized acetate of lead is obtained by evaporation. Litharge, or other oxides of lead, may also be used in this process. This salt crystallizes in acicular masses, when its hot concentrated solution is set aside to cool, and in this state it is generally found in commerce; by slower evaporation, it yields truncated and flattened quadrangular and hexaëdral prisms, cleavable parallel to the lateral and terminal planes of a right-rhombic prism, which may be considered as its primary form. (Brooke, *Ann. of Phil.*, 2nd series, vi., 374.) These crystals are permanent in ordinary states of the atmosphere, but they effloresce at about 100°, and *in vacuo* over sulphuric acid. Acetate of lead has a singularly sweet, and somewhat astringent taste: its sp. gr. is 2.57. Water boiled upon it dissolves 0.29, and retains when cold 0.27 of its weight of it. (Bostock.) It does not raise the boiling-point of water. When heated, the crystals fuse at about 130°; at 212° the liquid salt boils, and having lost its water of crystallization, concretes into a lamellar mass; at a higher temperature, this fuses, then gives out acetic acid, pyroacetic spirit, and carbonic acid, and the residue of its destructive distillation is charcoal, and very finely-divided lead, in a highly-combustible state.

Acetate of lead is partially decomposed by carbonic acid, which throws down a portion of carbonate of lead, and the acetic acid which is set free, protects the remaining solution from further precipitation; the carbonic acid contained in the atmosphere partially decomposes acetate of lead, in this way. All the acids and their salts, which form insoluble or difficultly-soluble compounds with oxide of lead, also decompose this salt, and these are very numerous; and in consequence of the facility with which the insoluble salts of lead are decomposed, when diffused through water, by sulphuretted hydrogen, such applications of the acetate are of frequent occurrence. The crystals of this salt are represented by ($\mathrm{Pl} + ac' + 3\,q$), they consist of

				Berzelius.	Thenard.
Oxide of lead	1	112	58.95	58.71	58
Acetic acid	1	51	26.84	26.97	26
Water	3	27	14.21	14.32	16
Crystallized acetate of lead	1	190	100.00	100.00	100

DIACETATE OF LEAD. ($2\ \mathrm{Pl} + ac'$.) This salt is formed, according to Thomson, by boiling a solution of acetate of lead, with the requisite atomic proportion of litharge: on evaporation, it falls as a white crystalline sediment, of a sweet astringent taste, and soluble in water. Its constituents are

			Thomson.
Oxide of lead	2	224	61.2
Acetic acid	1	51	14.0
Water	10	90	24.8
Hydrated diacetate of lead	1	365	100.0

TRISACETATE OF LEAD. ($3\ \mathrm{Pl} + ac'$.) This tribasic acetate, has long been known, in solution, under the name of *Goulard's Extract of Lead.* It is the *Liquor plumbi subacetatis* of the Pharmacopœia. It is prepared by boiling excess of finely-powdered protoxide of lead in a solution of the acetate, or in dilute acetic acid. About 15 parts of litharge to 10 of the crystallized acetate, may be used; about 6 parts are dissolved; and the solution, filtered and evaporated, leaves an uncrystallizable and anhydrous *trisacetate.* It is soluble in water, but insoluble in alcohol. It has an alkaline reaction. It is a very susceptible test of the presence of carbonic acid, which it absorbs from the atmosphere, and suffers a proportionate decomposition: even distilled water is seldom so free from carbonic acid as not to be rendered turbid on the addition of a few drops of the solution of this salt. It forms precipitates in all solutions which affect the neutral acetate, and it throws down the greater number of organic compounds, hence its use in many cases of analysis. The anhydrous salt consists of

				Berzelius.
Oxide of lead	3	336	86.82	86.77
Acetic acid	1	51	13.18	13.23
Trisacetate of lead	1	387	100.00	100.00

HEXACETATE OF LEAD. ($6\ \mathrm{Pl} + ac'$.) When 1 part of acetate of lead and 2 of litharge are boiled together, or when acetate of lead is decomposed by excess of ammonia, a white powder is obtained, of very sparing solubility, and consisting of

				Berzelius.
Oxide of lead	6	672	89.60	91.3
Acetic acid	1	51	6.80	5.7
Water	3	27	3.60	3.0
Hydrated hexacetate of lead	1	750	100.00	100.0

ACETATE OF ANTIMONY. This salt, formed by digesting the protoxide in vinegar, was once employed as an emetic.

ACETATE OF BISMUTH may be formed by adding nitrate of bismuth to a concentrated solution of acetate of potassa; a precipitate falls, which redissolves on the application of heat, and afterwards affords scaly crystals. The addition of acetic acid to nitrate of bismuth prevents its precipitation when diluted. (Morveau, *Ency. Méthod.* CHIMIE.)

ACETATE OF URANIUM forms four-sided prismatic crystals of a yellow colour.

ACETATE OF CERIUM. Recently-precipitated oxide of cerium readily dissolves in acetic acid, and yields small crystals on evaporation, of a sweetish taste, permanent, and readily soluble in water. (Hisinger and Berzelius: Gehlen's *Jour.*, ii. 414.)

PROTACETATE OF MERCURY ($\text{Hg} + ac'$) is most readily formed by mixing a solution of protonitrate of mercury with acetate of potassa. For this purpose dissolve three ounces of mercury in about four ounces and a half of cold nitric acid, and mix this solution with three ounces of acetate of potassa previously dissolved in eight pints of boiling water, and set the whole aside to crystallize, which takes place as the liquor cools, and the acetate of mercury then separates in the form of micaceous crystalline plates, which are to be washed in cold water, and dried on blotting-paper. (*Edin. Phar.*) In preparing this salt, the quantity of water for dissolving the acetate need not be so large as above directed, one pint being sufficient, but it is necessary to pour the mercurial solution into the acetate. This salt has an acrid taste, and is very difficultly soluble in water, requiring, according to Braconnot (*Ann. de Chim.*, lxxxvi., 92), 600 parts of water. It is insoluble in alcohol. It was once used in medicine. It consists of

				Dumas.	Garot.
Protoxide of mercury	1	208	80.2	80.66	79.7
Acetic acid	1	51	19.8	19.34	20.3
Protacetate of mercury	1	259	100.0	100.00	100.0

PERACETATE OF MERCURY ($hg + 2o + ac'$) is obtained by boiling peroxide of mercury in acetic acid; on cooling, nacreous crystals are deposited, readily soluble in water, and composed of

				Stromeyer.	Garot.
Peroxide of mercury	1	216	66.9	67.664	67.
Acetic acid	2	102	33.1	32.336	33.
Peracetate of mercury	1	318	100.0	100.000	100.

ACETATE OF SILVER. ($\text{Ag} + ac'$.) This is a very difficultly-soluble salt, and much resembles the protacetate of mercury. It is deposited in lamellar crystals when acetic acid is added to a strong solution of nitrate of silver; it is abundantly precipitated from a mixed solution of nitrate of silver and acetate of soda. Its difficult solubility renders nitrate of silver useful occasionally as a test of acetic acid. It consists of

				Dumas.
Oxide of silver	1	116	69.46	70.33
Acetic acid	1	51	30.54	29.67
Acetate of silver	1	167	100.00	100.00

ACETATE OF ALUMINA. This salt is extensively employed by dyers and calico-printers as a basis or mordant for fixing a great variety of colours: it is usually made by mixing solutions of alum and acetate of lead. About 3 lbs. of alum are dissolved in eight gallons of water, and a pound and a half of sugar of lead stirred into it; a copious formation of sulphate of lead ensues, which is allowed to subside, and the clear liquor holding acetate of alumina and a portion of undecomposed alum in solution, is then drawn off; a portion of pearlash and chalk being added to it previous to use, in order to saturate any excess of acid. This salt is also produced by the mutual decomposition of acetate of lime and alum. A gallon of a solution of acetate of lime, of a specific gravity of about 1.050, equivalent to nearly half a pound avoirdupois of dry acetic acid, is employed for every $2\frac{3}{4}$ lbs. of alum. (Ure's *Dictionary*, Art. ALUMINA.)

Acetate of alumina, formed by digesting recently-precipitated alumina in acetic acid, may be procured in deliquescent acicular crystals of an astringent taste, and containing, according to Richter, 73.81 acid + 26.19 alumina: hence it is probably a *binacetate.*

The solution of this salt becomes turbid when heated, and again transparent on cooling; a curious circumstance, first observed by Gay Lussac, and depending upon a temporary decomposition of the acetate; whether the deposit be alumina or a subacetate seems not understood; it is prevented in the solutions used by the calico-printer, by excess of alum.

PYROACETIC SPIRIT; PYROACETIC ETHER; ACETONE. This product was obtained by Derosne, along with acetic acid, by the destructive distillation of acetate of copper. (*Ann. de Chim.*, lxiii., 267.) Chenevix obtained it from other acetates, and it has subsequently been examined by Macaire and Marcet (*Ann. of Phil.*, *N. S.*, viii., 69), and by Liebig and Dumas. (*Ann. de Chim. et Phys.*, xlix.) When acetate of lime is carefully distilled, it yields a considerable portion of this product; it may be freed from water and empyreumatic oil, by repeated rectification over chloride of calcium. It is, when pure, a colourless limpid liquid, highly inflammable, of a peculiar penetrating and somewhat aromatic odour; specific gravity = 0.792 at 64°. It boils at 132°, and the density of its vapour is, according to Dumas, 2.019. It mixes in all proportions with water, alcohol, ether, and oil of turpentine; it is not affected by exposure to air; it may be distilled without change over the caustic alkalis and chloride of calcium; but when mixed with fixed alkaline solutions, and exposed to air, oxygen is absorbed, and a brown matter slowly formed. It dissolves saline substances generally, less copiously than alcohol. Distilled with chloride of lime it yields *chloroform.* (p. 1106.) Gaseous chlorine is absorbed by it, with the evolution of muriatic acid and the formation of a peculiar oily fluid of the specific gravity 1.33, and composed of $({}_{3}\,car + {}_{2}\,h + c + o.)$ Liebig.

The ultimate components of pyroacetic spirit appear to be

				Dumas.	Macaire and Marcet
Carbon	3	18	62.0	62.5	55.30
Hydrogen	3	3	10.4	10.2	8.20
Oxygen	1	8	27.6	27.3	36.50
Pyroacetic spirit	1	29	100.0	100.0	100.00

The product analyzed by Macaire and Marcet was probably not pure. Liebig and Dumas have observed that *anhydrous acetate of baryta* is resolved by heat into pyroacetic spirit and carbonate of baryta, and it will be found that

1 equivalent of acetic acid = 51, or $(4\, car + 3\, h + 3\, o)$
may be exactly resolved into
1 equivalent of pyroacetic spirit = 29, or $(3\, car + 3\, h + o.)$
1 ———— carbonic acid = 22, or $(car + 2\, o.)$

Pyroxylic Spirit; Pyroligneous Spirit; Bihydrate of Methylene. (From μεθυ, *wine*, and υλη, *wood*.) We owe the discovery of this highly-interesting product to Mr. Philip Taylor (*Quart. Jour. of Science*, xiv., 436); it was afterwards examined by Macaire and Marcet (*Bibl. Univ. and Ann. of Phil.*, *N. S.*, viii. 62), then by Döbereiner, by Colin, and by Liebig, and lastly by Dumas and Peligot. (Dumas, *Chim. App. aux Arts*, v., 419.) When wood is subjected to destructive distillation there is formed, along with the tar, acetic acid, and other products which I have already described, a variable portion of a highly-inflammable and volatile liquid; it may be separated, to a certain extent, from the water and acetic acid, by distillation and separation of the first products; and these, redistilled and rectified over quicklime, at length afford the pure *pyroxylic spirit*, or *alcohol of wood*. If it contain ammonia, it must be neutralized, previous to its last rectification, by sulphuric acid*.

Pyroxylic Spirit is a limpid liquid, of a peculiar odour, partaking of that of alcohol and acetic ether, with an aromatic taint which has been compared to peppermint. Its taste is hot and pungent. Its specific gravity at 60° is about 0.800. It boils at 150°; if heated in a retort, even in a water-bath, the sudden extrications of its vapour are troublesome, and may be prevented by the presence of a little mercury, which equalizes the distribution of heat. The density of its vapour is 1.115. It is not altered by exposure to air, but when subjected to the slow action of the black platinum (831,) it yields *formic* acid; not acetic acid, as is the case with alcohol.

Chlorine acts less powerfully on pyroxylic spirit than on alcohol, and heat is required to accelerate their mutual action; it gives rise to the production of two liquids of very different degrees of volatility; that which is least volatile forms a crystallizable compound with ammonia. Chloride of lime acts upon pyroxylic spirit as it does upon alcohol; it also dissolves potassa and soda with similar phenomena. It dissolves baryta with the evolution of heat; and with solution of potassa and sulphuret of carbon, it forms a product which resembles Zeise's hydroxanthate of potassa. Its solvent powers, in regard to *salts*, closely resemble those of alcohol, and it may be substituted for alcohol in the preparation of fulminating silver, though the action is less violent and the product smaller in quantity. It dissolves the resins, and may be used as an excellent substitute for alcohol in all varnishes; indeed its superior volatility renders it preferable.

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* The experiments which have been made upon pyroxylic spirit, show its close connexion with alcohol, and lead us to suspect that, at no very remote period, *alcohol* will rank among the other extraordinary products which are derived from *lignin*. Although this *spirit* has not, I believe, as yet been rendered palatable, or resorted to as a stimulant, it is much used as a substitute for alcohol in the manufacture of varnishes and other purposes of the arts; it is also commonly employed (often under the name of *naphtha*) to burn in lamps, as a cheap substitute for spirit of wine. The chemical characters of *pyroxylic spirit*, as opposed to those of *alcohol*, are apparently sufficient, when carefully observed, to enable us satisfactorily to distinguish them; but articles are imported under the name of *pyroligneous ether, spirit*, &c., which are most suspiciously identical with alcohol, and which, if not closely examined, may lead to serious frauds upon the revenue: strong alcohol, disguised as to smell and taste, as in those respects to resemble pyroxylic spirit, has already been found in the market.

Protohydrate of Methylene. When 1 part of pyroligneous spirit is distilled with 4 of sulphuric acid, abundance of gas is evolved; when this is collected over mercury, it is found to consist of carbonic and sulphurous acids, which may be abstracted by potassa, and of *hydrate of methylene*, a gaseous body, having a specific gravity = 1.61, and composed of

	Sp. Gr.	
1 volume carbon vapour	0.8432	
2 ——— hydrogen gas	0.1376	
1 ——— aqueous vapour	0.6200	
	1.6008	(Dumas.)

This gas, therefore, according to Dumas, is isomeric with alcohol, and the vast difference in their respective properties depends upon the different densities of their hydrocarbon; the hydrogen and carbon which constitute 1 volume of alcoholic hydrocarbon, forming 2 volumes of methylic hydrocarbon.

This gas is colourless, of an ethereal odour, and burns with a flame resembling that of alcohol; water dissolves about 37 times its volume of it, at 65°, and acquires an ethereal odour and pungent taste: it is more soluble in alcohol and in pyroxylic spirit; it also dissolves in sulphuric acid, and is again evolved when water is added. It is presumed to consist of 1 atom of methylene and 1 of water.

Combinations of Methylene with the Hydracids. The hydracids act upon pyroxylic spirit, producing compounds analogous to the ethers of those acids, the water of the pyroxylic spirit being thrown off, and replaced by the acid, in such a way that each volume of the new compound includes 1 volume of methylene and 1 volume of the acid; these compounds are neutral, and show no indications of their included acids to tests, till the combination is destroyed by a red-heat or by inflammation.

Muriate of Methylene. This compound is best obtained by heating a mixture of 2 parts of chloride of sodium, 1 of pyroxylic spirit, and 3 of sulphuric acid; a gas is evolved, which may be received over water, and which is pure muriate of methylene, any impurities being abstracted by the water. This gas is not condensible at 0°, it is colourless, of an ethereal odour, and sweet taste, and burns with a greenish-white flame. Water at 60°, dissolves 2.8 volumes. It is quite neutral, and gives no precipitate with solution of nitrate of silver, resembling in these respects muriatic ether. Its density, determined by experiment, is 1.736, and analysis shows that it contains 1 volume of methylene. As the density of muriatic acid gas is = 1.2474, it is obvious that this ether is composed of 1 volume of methylene, and 1 volume of muriatic acid gas, condensed into 1 volume, for

		Sp. Gr.
1 Volume of methylene		0.4904
1 „	Muriatic acid gas	1.2474
1 „	Muriate of methylene	1.7378

COMBINATIONS OF METHYLENE WITH THE OXYACIDS. The action of the oxyacids upon pyroligneous spirit, gives rise to two classes of products; the one corresponding to the compound ethers formed by alcohol; the other analogous to the sulphovinic or phosphovinic acids. The first are neutral, and contain 1 atom of methylene, 1 atom of acid, and 2 atoms of water; they are more volatile and more stable than the corresponding alcoholic compounds.

SULPHATE OF METHYLENE is produced in the form of a heavy oil-like liquid, during the distillation of 1 part of pyroxylic spirit with 8 or 10 of sulphuric acid; when the oil is purified, it has an alliaceous odour; its specific gravity is 1.324; when anhydrous it admits of redistillation without decomposition; cold water slowly decomposes it, but boiling water instantaneously, resolving it into regenerated pyroxylic spirit, and into *sulphomethylic acid;* it is also decomposed by the hydrated alkalis.

The composition of this oil is stated by Dumas to be 22.5 methylene, 63.3 sulphuric acid, 14.2 water.

In regard to the other combinations of methylene, I must refer to the authorities quoted, or to Dumas. (*Chim. App. aux. Arts*, v.)

According to Dumas and Peligot, *pyroxylic spirit* is composed of

				Dumas.
Carbon	2	12	37.4	37.97
Hydrogen	4	4	12.6	12.40
Oxygen	2	16	50.0	49.63
Pyroxylic spirit	1	32	100.0	100.00

These numbers are equivalent to

Olefiant gas	1	14	43.8
Water	2	18	56.2
Pyroxylic spirit	1	32	100.0

But the term *methylene* is applied, not to olefiant gas, but to a *hydrocarbon* of which 1 *volume* contains 1 atom of carbon and 1 of hydrogen, so that its *density* is just half that of olefiant gas, being, according to Dumas, 0.4904; and in representing it by the equivalent 14, it is assumed that its *atom* corresponds to *two volumes:* if its equivalent be called 7, it will then correspond with its density, in reference to hydrogen, as = 1, and in that case, pyroxylic spirit will be represented by

				Vols.	Sp Gr.
Methylene	1	7	43.8	1	0.490
Water	1	9	56.2	1	0.625
Pyroxylic spirit	1	16	100.0	1	1.115

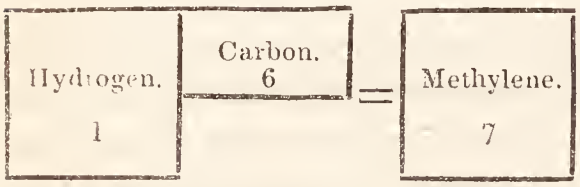
And the *gaseous hydrate of methylene* called above, the *protohydrate*, will consist of

				Vols.	Sp.Gr.
Methylene	2	14	60.9	2	0.980
Water	1	9	39.1	1	0.625
Dihydrate of methylene	1	23	100.0	1	1.605

The *muriate of methylene*, in reference to this view, will then consist of

				Vols	Sp. Gr.
Methylene	2	14	27.5	2	0.980
Muriatic acid	1	37	72.5	2	2.494
	1	51	100.0	2	1.737

The nature of *methylene* or the base of pyroxylic spirit requires further examination, but if the preceding views be correct, it furnishes the compound of 1 atom of carbon and 1 of hydrogen, which was required to complete the series of hydrocarbons: its formula is $(car + h)$ and its equivalent 7, and in reference to the diagrams which I have elsewhere employed, it may be represented as in the margin.



It is impossible to review the facts which have been adduced respecting the atomic constitution of the various hydrocarbons, and their relations to oxygen and other substances, in the character of *bases*, without favourable anticipations in regard to the ultimate influence of these inquiries, in simplifying our views of organic compounds. Some of the theoretical inferences bearing upon this subject have perhaps been carried too far, and others are purely hypothetical, but it is only by thus viewing the question in different lights, and by associating and comparing the experimental results, that the problem respecting the atomic constitution of organic compounds can be ultimately solved; it will then, no doubt be found that the complexity and incongruities which hang over the subject are *apparent* only, and that the fundamental doctrines of organic chemistry will admit of some simple enunciation.

LACTIC ACID. This acid, as its name imports, was originally discovered in *sour milk* (Scheele, *Opusc:* ii. 101,) it was then recognised by Berzelius, in many animal fluids, and afterwards by Braconnot, as a product, along with acetic acid, of the sour fermentation of rice-meal, wheat-paste, the juice of the beet-root, and other vegetable substances; he gave it the name of *nanceic acid* (from Nancy, the place of his residence.) It has also been termed *Zumic acid* (from ζυμη, *leaven.*) It was supposed to be a compound of acetic acid with organic matter, but the error of that conclusion has been proved by Pelouze and Jules Gay Lussac (*Ann. de Chim.*, LII., 410.) It has been found by Coriol combined with lime and magnesia, in the fermented infusion of *nux vomica.* (*Jour. de Phar.* xix., 155, 373.)

Lactic acid may be obtained as follows:—Expose the expressed juice of beet-root to a temperature between 75° and 85°; in some days fermentation comes on, and continues for about two months; when this has ceased, the juice is evaporated to the consistency of syrup, during which crystals of *mannite* separate: it is then treated by alcohol, which takes up lactic acid, and which may be to a certain extent purified, by evaporation, and solution of the residue in water; a portion of insoluble impurity remains: this aqueous solution of the impure lactic acid is then saturated by carbonate of zinc; the soluble lactate of zinc is separated by filtration, and crystallized; it is then redissolved in water, boiled with animal charcoal, and filtered whilst hot; on cooling, the *lactate of zinc* separates in white crystals, which are washed with alcohol, decomposed by baryta, and the lactate of baryta, which is soluble, is decomposed by sulphuric acid. By a similar process lactic acid may be obtained from thoroughly sour milk. The aqueous solution of the acid may be concentrated in vacuo, and finally rendered quite pure, by solution in ether, which leaves a little flocculent matter.

Lactic Acid is colourless, inodorous, very sour, of a syrupy consistence, and its specific gravity is 1.215; it attracts moisture from the air, and dissolves in all proportions in water and alcohol, and in smaller quantity in ether. It easily coagulates milk, and has a considerable solvent power over phosphate of lime, which induces Berzelius to regard it as the solvent of that salt in many animal fluids. Added to a strong solution of acetate of magnesia, it forms a granular precipitate of *lactate of magnesia*, and the odour of acetic acid is exhaled.

When lactic acid is cautiously heated, it first becomes more liquid, it then yields inflammable gases, acetic acid, and a white sublimate, which is *crystallized lactic acid*, and charcoal remains. These crystals, dried by pressure in bibulous paper and dissolved in alcohol, yield perfectly white rhomboidal tables, fusible at 225°, and volatile at 472°; this vapour again condenses in crystals, which when dissolved in water, yield an acid exactly resembling the original: according to J. Gay Lussac and Pelouze, the crystallized acid is anhydrous and consists of

Carbon	6	36	50.0
Hydrogen	4	4	5.6
Oxygen	4	32	44.4
Anhydrous lactic acid	1	72	100.0

The lactic acid, as it exists in the neutral lactates in their driest state, and exclusive of water of crystallization, carries with it one atom of water, or of the elements of water, and is therefore, in them, represented by 72 + 9 or 81; its formula being (6car + 5h + 5o.)

The syrupy acid includes 2 atoms of water, so that in combining with bases it throws off 1 atom, and retains 1, whilst the crystallized acid, in similar cases, resumes an atom of water. No *anhydrous lactate* therefore has been obtained.

CHARACTERS OF THE LACTATES. All these salts are soluble, and many of them are uncrystallizable. The *lactates of potassa*, and of *soda* are deliquescent and soluble in alcohol; they yield crystalline masses by evaporation *in vacuo*. *Lactate of ammonia* is deliquescent and uncrystallizable. *Lactates of baryta*, and *of lime* yield gum-like masses; those of *alumina*, of *peroxide of iron*, and of *copper* are uncrystallizable; *lactate of magnesia* is crystallizable, and *lactate of zinc* yields four-sided prisms, sparingly soluble in water and insoluble in alcohol; they contain 4 atoms of water. *Lactate of silver* forms white acicular crystals.

PUTREFACTIVE CHANGES OF VEGETABLE SUBSTANCES. The phenomena of vegetable putrefaction, or of *putrefactive fermentation*, have been very imperfectly investigated, and it is the general effects only of these changes, and not their causes, or intimate nature, that have been hitherto developed. Much that will be stated in the next chapter in reference to *animal putrefaction* applies also to that of vegetables; they are both occasionally productive of infectious poisons, but the effluvia of the latter are chiefly such as give rise to intermittent fever, whilst the former produce remittent and typhoid diseases. The circumstances and agents which I shall have occasion to notice as modifying, retarding, or accelerating animal putrefaction, are generally similarly effective in regard to vegetables, and in many other respects the two series of phenomena are closely analogous; but the almost uniform presence of nitrogen, sulphur, and phosphorus, in animal products, and their comparative rarity in those of the vegetable kingdom, render the putrefactive effluvia of the latter less fetid and disagreeable; ammoniacal compounds, and sulphuretted and phosphuretted hydrogen, being in the latter cases, seldom produced, or at all events, in insignificant proportion.

When moist vegetables are heaped together they undergo, in warm weather, a species of fermentation, attended by the evolution of heat to such an extent as sometimes to excite combustion, and therefore indicative of intense chemical action; of this, a familiar instance is afforded in the spontaneous ignition of hay which has been stacked in a humid state; it heats, smokes, and evolves a peculiar odour, and if not cooled by exposure to air, it breaks out into flame, or suffering a slower species of combustion, becomes charred and decomposed.

When vegetables putrefy in water, it frequently happens that the process is accompanied by the appearance of microscopic *animalcules*, and the death and decomposition of their successive generations, affect the products, and give them, in some instances, more or less of an animal character. These changes, like the former, are much affected by temperature and other circumstances. In stagnant water the soluble substances of the vegetable are first extracted, and the infusions thus produced are of course as various in the changes which they undergo, as in the nature of their contents: their decay is sometimes rapid and offensive; sometimes the water acquires a brown colour, and a tendency to mouldiness; and the residuary matters, which lie at the bottom, and are, therefore, out of the reach of air, are very slowly disintegrated and resolved into a black mud, in which carbon is predominant: such changes, however, are sometimes so tardy, that some kinds of wood, protected perhaps by resinous and other less-perishable products, have remained for centuries under water, and have retained their characteristic properties.

The influence of the destructive fermentation or putrefaction of various vegetable substances as *manures*, has already been mentioned (p. 878); and under the head of *Vegetable Extract*, I have noticed the brown residue of the gradual decay of plants. All these changes deserve to be closely investigated; they are not only interesting as matters of abstract chemical inquiry, but they have important and immediate bearings upon some of the most obscure parts of geology; those which relate to the destruction of the forests of the ancient world, to the changes which they have successively suffered in the depths of the ocean, and to their ultimate conversion into the varieties of *coal*.

Chapter VIII.

ANIMAL PRODUCTS.

The principal ultimate elements of animal substances are the same as those of vegetables, namely, carbon, hydrogen, oxygen, and nitrogen; but nitrogen is more generally present, and sulphur and phosphorus are more commonly superadded. The humidity of the proximate components, their organization, and their ultimate composition are such, as in many cases to render them extremely prone to change, after the loss of vitality; and the very circumstances which contribute to their permanence and stability whilst under the influence of life, are, apparently, those which after death, render them particularly susceptible of decomposition. The putrefaction of animal substances is distinguished from that of most vegetables by the nauseous stench which attends it, partly arising from the presence of sulphur and phosphorus in the gaseous products, and partly from other combinations, with the exact chemical nature of which we are unacquainted.

The *solids of animals* derive their soft, flexible, or elastic texture, partly from their peculiar retentive power in regard to water; for, though not wet or moist, in the common acceptation of the term, they sometimes contain four-fifths their weight of water, part of which may be squeezed out or dried off, when they become hard, brittle, or translucent, but again swell up and regain their former appearance on being immersed in water: this desiccation, however, always kills the part; if we perhaps except some among the lower orders of the animal creation, which are said to admit of being dried, and again revive when moistened. Under this view of the subject, therefore, a living animal may be regarded as a mass of organized matter, softened by water, probably to the amount of about three-fourths of its total weight. It has been ascertained that nothing but pure water gives the peculiar flaccidity and softness to which I have alluded: salt water, spirits, oils, and all other liquids, producing very different effects. When microscopically examined, these soft solids generally appear to be made up of small globular particles, of the nature of which, as far as muscular fibre is concerned, we shall have to speak afterwards.

When animal matter is subjected to *destructive distillation*, *ammonia* is a leading product; it is generally more or less saturated by carbonic, and occasionally by other acids, and often in the state of solid carbonate, or dissolved in water and contaminated by empyreumatic oil; the *salt* and *spirit of hartshorn* of old pharmacy, are products of this description, and the same are afforded by common bone, provided the *fat* has been previously separated; for animal, like vegetable fat, yields distinct products, being destitute of nitrogen. The *empyreumatic oil* formed in these processes, and often termed *Dippel's oil*, first passes over of a pale-yellow colour; it gradually becomes darker and thicker; but when redistilled with water, it is nearly colourless, of a penetrating odour, and gradually acquires a brown colour by exposure to air; it is alkaline, soluble in alcohol, inflamed by nitric acid, and by somewhat diluted nitric acid it becomes resinous; it is soluble in muriatic acid, and precipitated by sulphuric and nitric acids; and by alkalis in an altered and apparently resinous state. The *tar* associated with this oil, has been before noticed as a source of eupion, (985.) This, and the oil, have been examined by Unverdorben, who has found in them no less than four distinct substances, which he considers as salifiable bases; namely, 1 *odorin* (from *odor*), obtained by saturating the ammonia in the rectified oil, by nitric acid, then pouring off the oil, and distilling it in a water-bath; the first portion which passes over is *odorin;* it has the concentrated odour of *Dippel's oil*, and combines with the acids, forming peculiar oily salts; it also forms double salts, in conjunction with several other salifiable bases. 2. *Animin*, (from *animal*,) is contained in the oil which succeeds the odorin; this, washed with water, saturated with sulphuric acid, and distilled, leaves *animin;* it is an oily fluid, having the odour of purified salt of hartshorn. 3. *Olanin*, (from the first syllables of *oleum animale*) remains in the retort after the odorin and animin have distilled over; when washed with water, it resembles a fat oil; and when exposed to air it becomes brown, and is converted into *fuscin*. 4. *Ammolin*, (from the first syllables of *ammonia* and *oleum*,) is obtained from the crude or unrectified animal oil. Unverdorben has also described another salifiable base, which he obtains from animal empyreumatic oil, and which, as it forms crystallizable compounds with the acids, he has termed *krystallin*. The details of these researches, which are complicated, are contained in *Poggendorff's Journal*, (viii. and xi.,) and abstracts of them are given by Berzelius and Gmelin; it appears probable, that some of the supposed *educts*, are produced by the various processes to which the oil is submitted for their separation; those who are engaged in researches connected with this subject, must consult the original papers.

The *gaseous products* of the destructive distillation of animal matter are extremely various, and easily modified in quality as well as quantity, by the manner in which the process has been conducted; the *charcoal* which remains after the separation of the volatile principles, has been already repeatedly noticed as peculiarly adapted to the removal of colour, odour, and taste, from various solutions; and in consequence of the salts which it contains, and especially the phosphates, it resists incineration, and requires particular management when its incombustible contents are to be separated.

PUTREFACTION AND PRESERVATION OF ANIMAL MATTER. The phenomena of animal putrefaction are extremely varied and complicated, and are easily affected by extraneous causes, such as temperature, air, moisture, and other agents. The changes which are thus produced in individual parts of animals, will be noticed in the sequel, but a few general observations may be made here, in reference chiefly to circumstances which influence or modify the process.

The influence of *temperature* is commonly known; every one is acquainted with the preservative powers of *cold;* and when animal matters are subjected to higher temperatures than those of warm climates, they undergo changes which do not come within the meaning of the term putrefaction. The greater number of animal substances are indefinitely preserved at or below the freezing-temperature, and when slowly thawed, they generally regain their original characters; it is in this way that supplies of animal food are kept in a fresh state in many parts of the north of Europe, and that fish is preserved for the London market; a remarkable instance of the preservative power of cold was exhibited in the ancient elephant, found incased in a mass of ice, at the mouth of the river Lena, in Siberia.

Moisture is another essential to putrefaction; when flesh is carefully and thoroughly *dried*, either by a current of warm and dry air, or by other methods which do not alter its composition, it resists decay; it has thus occasionally happened that corpses have been preserved by accidental desiccation; and animal substances which are either naturally dry, or rendered so by art, retain their nutritive powers, and resume their former appearance when cautiously moistened. The various forms of gelatine, whilst kept dry, are imperishable; whilst in aqueous solution, or in their original humid state, they are the most perishable of the animal proximate principles, as skin and the varieties of tremulous jelly show.

Air, or at least *oxygen*, if not absolutely essential to, is a powerful promoter of putrefactive changes, and under certain circumstances, its exclusion, indefinitely retards them*; it is thus, that in Appert's method of preserving animal and vegetable food, the substances are hermetically sealed in tin canisters, and then par-boiled; the included oxygen becomes converted into carbonic acid, or enters into other combinations. Oil, butter, suet, and such substances, are sometimes similarly effectual; and potted and preserved meats, when covered with a film of fatty matter, itself not prone to change, are in that way preserved from the contact of air. The manner in which various saline substances, and especially common salt, act, is not very clearly understood; it is partly by desiccation, or abstraction of moisture, and by a corrugating power over the animal fibre; and partly by the production of new compounds arising out of the neutral action of the salt employed, or its elements, upon the organic matter: the preservative powers of corrosive sublimate, sulphate of copper, acetate of copper, the corresponding salts of iron, and very many other similar compounds, are of the same description. These antiputrefactives are generally coagulators of albumen; and alcohol, kreosote, and some of the dilute acids, have the same power, and are effective preservatives. Among vegetable products, the various forms of tannin act apparently by direct union with the animal fibre, producing combinations which are insoluble in water, which resist the joint agency of air, heat, and moisture, and which admit of desiccation. Sugar, which is sometimes employed as a substitute for salt, acts apparently by its affinity for water; and meat, which has been deprived by these or other means, of only a part of its water, becomes infinitely less susceptible of putrefactive changes. The ancient Egyptians, seem to have availed themselves of almost all these methods of preservation in embalming their mummies, as appears from the researches of Dr. Granville and of Mr. Pettigrew, in reference to this curious subject.

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* Hence, the rapidity of putrefactive changes in pure oxygen, and their retardation in gases which either do not contain it, or in which it is held by superior attractive power. Even under water, when oxygen is strictly excluded, putrefaction is greatly retarded and modified in its results. Meat immersed in water previously boiled to expel air, and then covered by a layer of oil, to prevent its subsequent absorption, may long be kept fresh; the presence of iron-filings and of sulphur in the water, assist in this species of preservation.

When the flesh of animals is subjected to the action of running water, it is occasionally converted into a peculiar fatty matter, which has been termed *adipocere* (from *adeps* and *cera ;*) it somewhat resembles spermaceti in appearance, and was supposed to partake of the properties of *fat* and *wax*. In the year 1789, Fourcroy communicated to the Royal Academy of Sciences at Paris a curious account of the changes sustained by the human bodies interred in the cemetery of the Innocents in that city; some of these had been piled, for a succession of years, closely upon each other, in large cavities containing from one thousand to fifteen hundred individuals. One of these graves, opened in Fourcroy's presence, had been full, and closed for fifteen years. When the coffins were opened, the bodies appeared shrunk and flattened, and the soft solids were converted into a brittle cheesy matter, which softened and felt greasy when rubbed between the fingers. The bones were brittle; and the texture of the abdominal and thoracic viscera no longer discernible, but lumps of fatty matter occupied their places.

It is not uncommon to find masses of this *adipocere* in the refuse of dissecting-rooms, especially when heaps of such offal are thrown into pits and wells, and suffered gradually to decay. The carcasses of cats and dogs, and other drowned animals, also often exhibit more or less of a similar change; and Dr. Gibbes (*Phil. Trans.*, 1794,) found that lean beef, secured in a running stream, underwent a change into fat in the course of three weeks. Fat, and the adipose parts of animals, also undergo a change in appearance and composition under similar circumstances: tallow becomes brittle and pulverulent, and may be rubbed between the fingers into a white soapy powder.

Gay Lussac, Chevreul, and some others, conceive that muscular fibre, skin, &c., is not convertible into adipocere, but that this compound results entirely from the fat originally present in the substance, and that the fibrin is completely destroyed by putrefaction. There are cases, however, in which the conversion of muscle and of fibrin into fat can scarcely be doubted, (*Ann of Phil.*, xii., 41,) though the propriety of applying the term *adipocere* to such fatty matter may be questionable. The action of very dilute nitric acid upon some of the modifications of albumen is also attended by their conversion into an adipose substance.

The chemical properties usually ascribed to adipocere are the following: it fuses at a temperature below 100°; it dissolves in boiling alcohol, and the greater portion is deposited as the solution cools; the action of ether resembles that of alcohol; it is saponified by the fixed alkalis, but not by ammonia. It would appear, however, from Chevreul's experiments, that adipocere is not a mere modification of fat, or a simple product, but that it is a *soap* composed of margaric acid and ammonia.

Connected with the putrefactive changes of organic matter are those extraordinary products of death and of disease known under the name of *infectious* and *contagious matters ;* their chemical nature is quite unknown, except in so far that they appear to possess the general characters of organic compounds, and are decomposed and resolved into harmless products by certain chemical agents; amongst which heat, chlorine, and a few of the gaseous acids are commonly resorted to for the purpose*. When articles of clothing or of merchandise which are infected with contagious matter are exposed for some time to a temperature of about 220°, they become disinfected, especially if at the same time subjected to a current of air. Washing in soap and water, boiling or steaming, are equally effective. In regard to *fumigation*, chlorine is the most effective agent; the mode of applying it, and some of its compounds, in these cases, has already been mentioned. In dissecting-rooms, and in the examination of dead bodies, too much care and attention cannot be paid to the prevention of the evil consequences to which various forms and applications of infectious and contagious products give rise. Their extraordinary power of exciting various and dangerous diseases, either by pulmonary or cuticular absorption, or other introduction into the living system, are too well known, but of their *modus operandi* we are utterly ignorant; sometimes they produce anomalous and uncertain effects; at others they have a tendency to create poisons in the living system, resembling themselves; the *inoculation* of diseases, as of the small-pox, &c., is a similar case, in which the introduction of the smallest fraction of a grain of poisonous matter excites new and morbid actions, and terminates in the throwing off from the system of a poison corresponding in its properties with that from which it was derived†. The theory of infection and contagion is mysterious and curious in the extreme, but its further consideration would be foreign to this work. Of another matter also connected with this subject, namely, the influence and production of *malaria*, of *marsh-miasma*, and other poisonous exhalations of organic, but principally of *vegetable* origin, we are equally ignorant; they chiefly produce that extraordinary disease, the *ague*, or *intermittent fever*; and their nature is obscure and unintelligible.

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[*] In times of plague and other pestilence, the vicinity of smelting-furnaces was formerly resorted to as being least liable to the infectious visitation; the sulphurous and other acid fumes were doubtless the disinfectants. In such and similar situations, in chloride of lime manufactories, and in other chemical works, an immunity from certain diseases is consequently enjoyed, though others are sometimes engendered. It seems not impossible that the freedom which London enjoys from the spread of malignant diseases may, in part, be ascribed to the products of the combustion of coal, which always taint its atmosphere; the drainage, and the copious supply of water, contribute, however, essentially to the health of its inhabitants, for the effluvia from the offal of large cities, if not speedily and effectively cleared off, is, of course, productive of infinite mischief; even in London, the construction and management of the *sewers* requires much reform, and were it not for the *water-companies*, their evils would be more evident.

[†] Perhaps one of the most remarkable properties of some forms of infectious matter, is its permanency; retaining, as is frequently the case, its peculiar powers, for an indefinite period. Of this, the preservation and transmission of *dried* variolous and vaccine matter is a familiar instance. The infection of *scarlet fever* is sometimes retained for weeks and months by articles of wearing-apparel; in one instance, after a malignant form of that disease had prevailed in a house, it was fumigated with chlorine and white-washed, and every article of furniture and clothing cleansed and fumigated, with the exception of a handkerchief which had accidentally been overlooked, and to which the appearance of the disease after a period of two months, was probably attributable. Blankets and woollen goods seem especially retentive of such poisons, and in all doubtful cases should be burned.

§ I. OF THE BLOOD.

In the higher orders of animals, the blood is of a red colour; florid, and approaching to scarlet in the arteries, and deep purple in the veins. The specific gravity of the blood varies between 1.050 and 1.070, and its temperature in the healthy human body is about 98° or 100°. It has an unctuous or somewhat soapy feel, a slightly-nauseous odour, and saline taste. It appears homogeneous, or uniform, whilst circulating in its vessels, or immediately upon its removal from them; but when examined by a microscope, it is seen to consist of numerous red spherical particles floating about in a colourless transparent fluid; the former have been termed the *red globules*[*], the latter the *serous portion*, or *liquor sanguinis*. The accounts given by microscopical observers of the appearance and characters of the red globules vary; they seem to consist of a central or colourless nucleus, enveloped in a film of colouring-matter, the former insoluble, the latter soluble in water; they are said to be spherical in mammiferous animals, and elliptical in birds and reptiles; but upon this subject I must refer to physiological authorities, and especially to the observations of Mr. Bauer detailed and illustrated in Sir E. Home's "*Lectures on Comparative Anatomy.*"

Under ordinary circumstances, the blood, soon after it has been drawn from its vessels, gelatinises or *coagulates*, and the jelly, or coagulum, gradually separates into two parts; a liquid *serum*, and a soft clot or *crassamentum.* In the act of coagulation, the globules apparently coalesce and throw off the colouring-matter, which is generally diffused equably through the crassamentum so as to give it an uniform red colour; sometimes, however, it subsides, leaving a stratum of colourless coagulum, which, in inflammatory disorders, is called the *buffy coat* of the blood.

It is stated that blood, if rapidly frozen before it has time to coagulate, may be retained for an indefinite time in the frozen state, but that when thawed, it first liquefies, and then coagulates as usual; the coagulation is, at all events, much interfered with by temperature. Blood drawn from a vein in the arm at the temperature of 53°, coagulates in 4.5 minutes; at 98°, in 2.5 minutes; at 120° in 1 minute. Blood which coagulates in 5 minutes at 60°, remains fluid for 20 minutes at 40°, and requires 60 minutes for complete coagulation at that temperature. (Scudamore *on the Blood.*) When blood is received into a close vessel, its coagulation is somewhat retarded; it is accelerated in the exhausted receiver of the air-pump. When drawn in a full stream, it coagulates more perfectly and more rapidly than when in a very small stream. It appears probable that, in the act of coagulation, the temperature of the blood is very slightly increased, consistently with the laws of latent heat. These are, I believe, the principal facts which have been ascertained upon this subject; they throw no light upon the *cause* of the coagulation*. The ratio which the clot bears to the serum is variable, and partly dependent upon the shape of the vessel in which the blood is contained; "Two portions of blood were drawn from the same person, one being received and allowed to coagulate in a pear-shaped bottle, and the other in a pint basin; and the ratio of serum to clot was as 1000 to 1292 in the former, and as 1000 to 1717 in the latter. In fact, when a mass of coagulating blood is contained in a spherical vessel, the particles of fibrin, being little removed from a common centre, are more powerfully attracted towards each other, yield a denser clot, and squeeze out more serum than when the coagulation takes place in a shallow wide basin, where the particles are spread over a large surface; the clot of the former is compact and small; while that of the latter, being spongy, and hence retaining much serum within it, is large and abundant, though the actual quantity of solid matter is the same in both." (Dr. B. Babington, as quoted by Dr. Turner.)

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[*] It was supposed that the colouring globules were inherently *red* and soluble in water, but it has been shown by Dr. Young, that the effect of water is to dissolve the colouring-matter only, leaving the globule colourless; in this state the globular particles appear to have the properties of albumen. The diameter of the globules in human blood varies from $\frac{1}{6000}$ to $\frac{1}{4000}$ of an inch. (*Remarks on Blood and Pus*, in Dr. Young's *Medical Literature.*)

The spontaneous coagulation of the blood, and its resolution into serum and coagulum, forms, as it were, a step towards its analysis, and naturally leads to the separate examination of these, its apparent proximate components.

SERUM OF THE BLOOD. This is the pale, straw-coloured, or greenish-yellow liquid, which gradually oozes out of the cruor or crassamentum; it feels soapy, and has a saline taste, and a specific gravity = 1.027 to 1.030 at 50°. It usually constitutes about three-fourths of the blood, the pressed coagulum forming about one-fourth; it is *alkaline* to tests, slowly reddening turmeric, and rendering the blue of violets green; the readiest test of its alkalinity is litmus-paper reddened by acetic acid; to this it immediately restores the blue colour. When the serum is heated to about 150°, it becomes a soft solid, coagulating into a translucent mass, which, upon the continuance of heat, becomes more opaque, and gives out a small quantity of a yellowish alkaline liquid, which has been termed *serosity*; this characteristic property is due to the presence of *albumen*, the most important proximate animal principle; the serum also contains a small but variable portion of *fat*, and of saline substances.

Marcet and Berzelius have each given an analysis of the serum of human blood; the following are their results. (*Medico-Chirurgical Transactions*, vol. ii.; *Annals of Philosophy*, vol. ii.)

	Marcet.
Water	900.
Albumen	86.8
Muriates of potassa and soda	6.6
Muco-extractive matter	4.0
Carbonate of soda	1.65
Sulphate of potassa	0.35
Earthy phosphates	0.60
	1000.

	Berzelius.
Water	905.0
Albumen	80.0
Muriates of potassa and soda	6.0
Lactate of soda, with animal matter	4.0
Soda and phosphate of soda with ditto	4.1
Loss	0.9
	1000.

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* The cause of the coagulation of the blood is unexplained; it is true that it apparently consists in the aggregation of its globules, but we are ignorant of what it is which prevents this effect in one case and promotes it in another; why the blood remains fluid whilst circulating, and under other circumstances; and why it occasionally coagulates, *when required so to do*, as in hæmorrhage, to plug up the bleeding vessel, &c. We have no proof that the blood either receives or emits anything essential to its coagulation.

Albumen. This substance, which is the leading ingredient of the blood, occurs in two states, liquid and solid; in the former state it is contained in the serum, and in many of the secretions; in the latter it constitutes a part of the crassamentum, and of almost all the solids of the animal fabric, such as muscle, bone, cartilage, tendon, ligament, and membrane; it is presented to us, in considerable purity, in the *white of egg*, whence the generic term, *albumen*, and it is from this source, and from the serum of the blood, that we chiefly obtain it for the purposes of experiment. I shall here describe the leading properties of albumen; and afterwards refer to its principal modifications.

The white of egg may be regarded as a combination of albumen with water; it contains small quantities of saline substances, which are inseparable in its liquid state. When it is evaporated at a temperature below 120°, it dries into a brittle, shining, transparent substance, of a pale-yellow colour, inodorous and tasteless. Its ultimate constituents, exclusive of saline matters and a trace of sulphur, are carbon, hydrogen, nitrogen, and oxygen; of these the relative proportions have been determined by Gay Lussac and Thenard, who analyzed the white of egg dried at 212°; and by Dr. Prout, who employed the dried serum of slightly-inflammatory blood; the following table shows its theoretical composition as contrasted with the experimental results:

				Gay-Lussac.	Prout.
Carbon	8	48	51.61	52.883	50.00
Hydrogen	7	7	7.53	7.540	7.78
Nitrogen	1	14	15.05	15.705	15.55
Oxygen	3	24	25.81	23.872	26.67
Albumen	1	93	100.00	100.000	100.00

White of egg, when heated to about 150°, *coagulates*, that is, becomes a white, translucent, and somewhat elastic substance, which, when cautiously dried, shrinks up and assumes the appearance of horn, becoming tough, yellowish, and insoluble in water. Two parts of white of egg and one of water entirely coagulate when duly heated; equal parts remain, under the same circumstances, semi-fluid; a mixture of one part of white of egg and ten of water becomes opaque, but is not coagulated; and a milkiness is perceptible when the albumen only forms a thousandth part of the solution. (Bostock, *Nicholson's Journal*, xiv., and *Med. Chir. Trans.*, i. and ii.) Fresh-laid eggs, and those which have been oiled upon the surface, do not perfectly coagulate when put into boiling water, in consequence, probably, of the dilute state of the albumen. One hundred parts of the fresh albumen of the egg, when carefully evaporated in vacuo, leave a residue = fifteen parts. One hundred parts of the coagulated white of a duck's egg (dried in vacuo with sulphuric acid) leave 13.65 parts, which, steeped in water, acquires its original appearance, but in four days only took up 68 of water, though it had lost 86.35. (Chevreul, *Mém du Muséum*, vii., 180; *Ann. de Chim. et Phys.*, xix., 46.)

When liquid albumen is made part of the voltaic circuit, it presents appearances dependent upon the power used, which, when considerable, excites so much heat as to coagulate it; but with a feeble power and the poles sufficiently distant, coagulation ensues most plentifully at the negative platinum-wire; a coagulum also forms at the positive wire, where acid is sparingly evolved. These phenomena are much interfered with by the evolution of gases at the respective poles, which occasion a froth, and the appearance of more extensive coagulation than actually occurs. (Brande, *Phil. Trans.*)

When coagulated white of egg is boiled for several hours, it shrinks up and becomes hardened, communicating traces of animal matter to the water. Heated by high-pressure steam in a copper digester to 400°, it blackens the interior of the vessel, and dissolves, leaving a small residue of unaltered albumen. The solution is brown, and has the odour of boiled meat (from osmazome?). This action deserves further investigation. (Gmelin, *Handbuch der Theoretischen Chemie*, ii., 1053. 3rd ed., Frankfort, 1827.)

White of egg soon runs into putrefaction, and evolves sulphuretted hydrogen. The serum of blood kept for two years in a well-stopped phial, blackened its interior, and became a stinking, pale, yellow liquid, still coagulable by heat, and containing hydrosulphate, carbonate, and acetate of ammonia, and a fetid volatile matter; a portion of yellowish-white purulent-looking matter, containing undecomposed albumen, remained at the bottom of the phial. Coagulated white of egg, even under water, long resists putrefaction.

One hundred parts of dried white of egg, subjected to destructive distillation, yielded carbonic acid, carburetted and sulphuretted hydrogen, prussic acid, carbonate of ammonia, partly in solution and partly sublimed, stinking volatile oil, and 14.9 of spongy difficultly-combustible charcoal, which, by incineration, left 2.21 of ash, composed of carbonate of soda, phosphate of soda, and phosphate of lime. (Hatchett.)

Nitric acid, dropped into a solution of albumen, forms a white, flaky precipitate, which is more or less abundant according to the state of dilution of the solution, and which is soluble in ammonia and potassa. When coagulated white of egg is kept for some weeks in very dilute nitric acid, it acquires a yellow colour, and if digested in boiling water it dissolves, and has acquired the properties of gelatine, and is precipitated by tan and muriate of tin. (Hatchett, *Phil. Trans.*, 1799.) Cold nitric acid, specific gravity 1.25, gradually tinges coagulated white of egg of a yellow colour, dissolving a little of it, and forming malic acid, with the evolution of nitrogen; its surface becomes tallowy, and, in twenty-four hours, it falls into a pale-yellow powder, which is acid, and composed of nitric, nitrous, and malic acids, with albumen; when thoroughly washed with water, it becomes more neutral, and of an orange-colour, still reddening litmus, and remaining insoluble in water, but soluble in caustic potash. (Berzelius, *Lehrbuch*, p. 38; Wöhler's Translation, Dresden, 1831.) When coagulated white of egg is digested in hot nitric acid, nitrogen, nitrous gas, carbonic acid, and prussic acid are formed, and a dark-yellow solution obtained, which is precipitated by the addition of water and ammonia, and which contains malic and oxalic acids, bitter matter, and fat. (Hatchett, *Phil. Trans.*, 1799.)

Sulphuric acid is a less powerful precipitant of albumen than nitric acid. Dilute sulphuric acid, dropped into an aqueous solution of albumen, occasions a precipitate which is soluble in excess of acid; ferrocyanuret of potassium throws it down. When coagulated albumen is digested in sulphuric acid, very slightly diluted, it yields a deep-crimson solution*. Coagulated serum, digested in sulphuric acid, diluted with six parts of water, converts it into acid *sulphate of albumen*, which, when edulcorated with cold water, becomes more neutral, and is soluble in warm water, forming a gelatinous solution, which is precipitated by sulphuric, muriatic, and nitric acids, and by the alkalis. (Berzelius, *Lehrbuch.*) Coagulated white of egg, digested in hot sulphuric acid, becomes carbonized without forming artificial tan. (Hatchett.)

When a solution of recently-fused phosphoric acid (pyrophosphoric acid) is added to a solution of albumen, it occasions an abundant precipitate: the acid gradually loses this property, and again acquires it by fusion and ignition. (Berzelius.)

Muriatic acid occasions a precipitate in albuminous solutions, and entirely throws down the albumen when aided by heat: but the precipitate is soluble in excess of acid, and in ammonia and potassa. A muriated albumen may be formed in the same way as the sulphate. (Berzelius.) Coagulated egg-albumen, digested in muriatic acid, gradually acquires a purple colour. (Hatchett.) Albumen, which has been precipitated by muriatic acid, often becomes reddish when collected and exposed upon a filter.

When coagulated seralbumen is digested in acetic acid, it becomes soft and transparent, and, aided by a gentle heat, dissolves with the evolution of a little nitrogen. This solution is precipitated by the alkalis, but a slight excess again renders it clear: it is also precipitated by sulphuric, nitric, and muriatic acids, and by ferrocyanuret of potassium. When this acetic solution of albumen is evaporated, it leaves a transparent sour residue, soluble in warm water acidulated by acetic acid. (Berzelius.)

Albumen is slowly soluble in liquid ammonia. In solution of potassa it becomes gelatinous, and yields a pale yellow-green solution, precipitable by acids and alcohol, and by acetic acid. Heated in liquid potassa, albumen evolves ammonia.

Alcohol and ether coagulate ovalbumen, but pure ether (free from alcohol) does not coagulate seralbumen. When serum is shaken with ether, it soon separates upon the surface, holding fatty matter in solution. (Gmelin.) Coagulated serum, digested in alcohol or ether, yields a solution of fatty matter.

Coagulated ovalbumen, when long boiled in water, becomes bulky and falls into pieces, and a small portion is dissolved: the filtered solution, evaporated at 212°, leaves a pale-brown film, and is alkaline; it is rendered turbid by mineral acids, acetic acid, and tincture of galls, and by many metallic salts.

When albumen, which has been cautiously dried at a low temperature (without coagulation), is triturated with four parts of water, it yields a solution resembling fresh albumen.

A solution of the white of an egg in a pint of water occasions no precipitate in lime, baryta, or strontia water, nor in solution of sulphate of lime. Some of the neutral salts render it more or less turbid, and it is copiously precipitated by solution of alum. Nitrate, acetate, and subacetate of lead are precipitated by albuminous solutions. One part of fresh ovalbumen in 2000 of water, or one of dried albumen in 10,000 of water, is rendered turbid by subacetate of lead. A four-hundredth part of liquid, or a two-thousandth of solid albumen, is precipitable by corrosive sublimate. (Bostock.) The precipitate is blackened by potassa, and is probably a compound of muriate of albumen and calomel. Nitrate of silver, muriate of gold, and of platinum, also precipitate albuminous solutions. These precipitates are mostly triple compounds of acid, albumen, and oxide, and several of them are redissoluble in excess of liquid albumen.

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* According to Raspail, when sugar is previously dissolved in the sulphuric acid, the albumen is coloured purple, which is deeper in proportion as the acid and sugar are in greater quantity.

Albumen is precipitated by tannin in the form of a yellow viscid combination. Water, holding a thousandth part of solid, or a two-hundredth of liquid, ovalbumen, becomes turbid after some hours by the addition of a solution of galls containing 2.5 *per cent.* of solid matter. (Bostock.)

The above are the principal chemical properties of liquid and solid albumen, as obtained from the egg and from serum of blood; several of their modifications will be noticed under other heads, such as FIBRINE, MILK, BILE, &c.

The cause of the coagulation of albumen is, in many cases, obscure and even inexplicable. It appears possible that the acids by which it is coagulated enter into combination with it, so as to form insoluble compounds; the same change probably happens with certain metallic salts, and with tan; its coagulation by alcohol has been ascribed to the abstraction of water. Having remarked the copious coagulation of albumen at the electro-negative pole in the voltaic circuit, I was induced to ascribe the fluidity of albumen to combined soda, the evolution of which seemed to cause its solidification; and it appeared possible that the acids, and even alcohol, might also occasion coagulation by the abstraction of soda; and that its more enigmatical coagulation by heat only, might be ascribed to the transfer of soda from the albumen to the water. It has been objected to this statement that the addition of alkali to coagulated albumen does not reproduce liquid albumen, and that acetic acid causes no coagulation; but when albumen is once coagulated, its properties are essentially modified, and acetic acid, or even acetate of soda, appear to form soluble compounds with it. (Gmelin.) Dr. Turner (*Elements of Chemistry*) supposes that albumen combines directly with water at the moment of being secreted, at a time when its particles are in a state of minute division; but as its affinity for that liquid is very feeble, the compound is decomposed by slight causes, and the albumen thereby rendered quite insoluble. The organization of albumen may certainly be concerned in its singular properties with respect to many coagulants: there are several albuminous fluids, which we shall hereafter refer to, which contain globules resembling those of the blood. In the voltaic coagulation of albumen, that which separates at the positive pole contains globules, which, under the microscope, resemble the blood-globules deprived of their colouring-matter. (Prevost and Dumas, *Ann. de Chim. et Phys.*, xxiii., 52.)

The readiest tests of the presence of albumen in fluids are its coagulation by heat, alcohol, and acids; when it is too dilute for such detection, it may be subjected to voltaic electricity, or tested by corrosive sublimate.

or by ferrocyanuret of potassium; the alkali should, in the latter case, be previously neutralized by acetic acid. It would appear, from Orfila's experiments, that white of egg is an antidote to the effects of corrosive sublimate when taken into the stomach, and that, if administered in sufficient quantity immediately after the reception of the poison, it prevents the progress of the symptoms. The white of one egg appeared sufficient to render four grains of the poison ineffective.

The readiness with which some metallic oxides are received into the system may perhaps be ascribed to their affinity for albumen, with which some of them form compounds not easily decomposable, and in which the metallic oxide cannot be detected by the usual tests, till they have been subjected to heat sufficient to decompose the organic matter. Mercury and silver are thus, in certain cases, detected in the secretions and excretions.

Crassamentum. Coagulum. These terms are applied to that part of the blood which spontaneously coagulates, and gradually contracts into a more or less dense mass. When cautiously removed from the serum in which it is immersed, and of which it always retains a considerable proportion, it may be regarded as principally consisting of *fibrin* and *colouring-matter.*

Fibrin. This substance may be separated from the serum and colouring-matter, by washing it in repeated portions of cold water; or by stirring recently-drawn blood with a stick, by which the coagulum will adhere to it, and it may then be conveniently washed in running water, till the serum and colour are extracted, and the fibrin remains in the form of a nearly colourless and fibrous substance, insoluble in cold water. Berzelius obtains fibrin by cutting the clot of blood into thin slices, drying them upon folds of blotting-paper to absorb the serum, and then washing with water till all soluble matters are extracted. The fibrin, however, still retains a little fat, for the removal of which it must be digested in ether, or in warm anhydrous alcohol.

Another mode of obtaining pure fibrin sometimes presents itself, which consists in removing the colourless layer which is occasionally observed upon blood drawn in inflammatory diseases, and termed the *buffy-coat;* when this is washed, digested in alcohol or ether, and dried, it may be considered as nearly pure fibrin: this substance appears to be identical with the part of blood termed *coagulable lymph.*

When fibrin is obtained by any of these means, it retains about three-fourths of its weight of water, which it loses by careful drying, and shrinks up into a translucent tough substance, very like horn; if its fat has not been separated, it is nearly transparent. When immersed in water it regains its original weight and softness; it has no smell or taste; when highly heated, it fuses, puffs up, burns, and leaves a spongy, shining coal. By destructive distillation it yields the usual products of azotised substances: the residuary coal is of difficult incineration, and amounts to about two-thirds *per cent.* of the weight of the original fibrin: the ash consists of phosphate of lime, a little phosphate of magnesia, and traces of iron and silica. The coal of the blood of the ox is more difficultly incinerated than that of human blood, in consequence of its containing more phosphate of lime.

Dried fibrin is insoluble in cold and in hot water, but, if long boiled, it shrinks, hardens, and becomes pulverulent; when the decoction is evaporated, it leaves a brittle yellow substance, of an agreeable flavour, and soluble in water; its solution is precipitated by infusion of galls, but it has not the other characters of gelatine; it has been termed *animal extractive*, and seems closely to resemble the substance which has been designated *osmazome*.

When fibrin is acted on by acids and by alkalis, it sometimes appears to perform the part of a base, and sometimes that of an acid. In sulphuric acid it swells up to a yellow jelly, but does not dissolve; heat is given out, and if the temperature is not kept down, the mixture chars and evolves sulphurous acid, but if kept cold, no such decomposition ensues. In water the jelly shrinks up, and when washed so as to get rid of excess of acid, it dissolves in water and forms a solution, from which sulphuric acid again throws it down in its gelatinous form; there appears therefore to be a neutral and soluble, and an acid and insoluble *sulphate of fibrin*. If the colouring-matter has not been entirely abstracted these solutions are red*.

Cold nitric acid forms, with fibrin, a gelatinous combination, resembling the sulphate; further digestion in the acid renders it yellow, and it then appears to be a compound of fibrin with nitric and malic acids.

Phosphoric acid, recently ignited and dissolved, acts upon fibrin like sulphuric acid, but if the acid has been kept in solution for eight or ten days the fibrin swells up in it into a soluble jelly, which is not thrown down by excess of the acid.

Acetic acid converts fibrin into a substance, soluble in warm water, and yielding a gelatinous mass on evaporation, differing from *gelatin*. Evaporated to dryness, the fibrin remains opaque and insoluble. The other acids added to this acetic solution, throw down precipitates which are compounds of fibrin and of the added acid. Caustic alkali precipitates the fibrin, and if added in excess, redissolves the precipitate.

Muriatic acid gelatinises dry fibrin, and then dissolves it into a blue liquid, or purple, if not previously freed from colouring-matter. No gas is evolved, and the solution, when diluted with water, lets fall a white precipitate which is a neutral *muriate of fibrin*, and has the general properties of the neutral sulphate: the remaining liquid retains its blue colour; saturated with ammonia, the colour disappears, and excess of ammonia renders it yellow: the blue colour, therefore, probably depends upon a new product.

Digested upon moist fibrin muriatic acid does not dissolve, but combines with it into the neutral muriate. Boiled in the acid, it is decomposed, nitrogen is evolved, and on evaporation a dark-brown ammoniacal compound remains.

The acid solutions of fibrin give a white precipitate with ferrocyanuret of potassium, which at first is soluble, but becomes permanent on adding excess of the precipitant. It is a compound of cyanuret of iron, fibrin, and hydrocyanic acid; it is insoluble in dilute acids, but soluble in caustic alkali. The red ferro-cyanuret of potassium (ferro-sesquicyanuret) throws down a more soluble precipitate than the above. These precipitates are very characteristic of fibrin, and of seralbumen, ovalbumen, and lactalbumen, and serve to establish the analogy, if not identity, of those modifications of this animal principle.

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* According to Braconnot, when water is added to the recent sulphuric solution of fibrin, and the mixture boiled for a few hours, and then saturated by chalk, the filtered solution contains a peculiar white matter, which he terms *Leucine Ann. de Chim. et Phys.*, xiii.) This is probably a compound of fibrin and sulphuric acid.

Fibrin is soluble in caustic potassa, even when the solution is very dilute; it gelatinises and then dissolves, and is precipitated, if not too dilute, by acids; a little sulphuretted hydrogen is always then evolved, which seems to indicate some further change.

Digested in alcohol, or in ether, fibrin yields fatty matter, which, according to Chevreul, is merely abstracted, but Berzelius regards it as a new product: it is soluble in alcohol, crystallizable, and reddens litmus.

The above account of the fibrin of the blood is chiefly abstracted from the works of Berzelius (*Lehrbuch*, iv., and *Medico-Chirurgical Trans.*, iii., 201.) Some of its other characters will be mentioned when speaking of *muscular fibre.*

The ultimate of analysis of fibrin agrees, as might be expected, in its outline, with that of albumen; there is, indeed, every reason for regarding them as different species of one organic principle. The atomic views which have been given of these animal principles, I do not quote, inasmuch as their combinations are not sufficiently definite to give their equivalents, and as we have no criterion by which to judge of their absolute purity, especially as concerns their variable proportion of water. The following are the results of the analyses:

	Gay Lussac and Thenard	Michaëlis.	
		Venous.	*Arterial.*
Carbon	53.360	51.374	50.440
Hydrogen	7.021	7.254	8.228
Oxygen	19.685	23.785	24.065
Nitrogen	19.934	17.587	17.267
Fibrin	100.000	100.000	100.000

COLOURING-MATTER OF THE BLOOD. HÆMATOSYN. HÆMACHROME. It is extremely doubtful whether the colouring-matter of the blood can be effectually separated from other principles, and especially from albumen. By stirring blood during coagulation, a considerable portion is diffused through the serum, from which it afterwards subsides. Vauquelin advises the digestion of the coagulum, drained of serum, in dilute sulphuric acid at a temperature of 160°. The liquid, filtered while hot, is to be evaporated to half its bulk, and nearly saturated with ammonia; the colouring-matter falls, and is to be washed and dried. (*Ann. de Chim. et Phys.*, i.) But in this process the hæmatosyn has probably undergone some change.

The chemical properties of the colouring-matter of the blood seem to show that it is a peculiar animal principle. It is soluble in cold water, and the solution, when boiled, deposits a brown sediment of altered colouring-matter. Muriatic, dilute sulphuric, and several of the vegetable acids, and the caustic and carbonated alkalis, readily dissolve it, and form solutions of different tints of red, and of a peculiar greenish hue when viewed by transmitted light. Nitric acid instantly renders these solutions brown, and decomposes the red principle. These and other properties, (*Phil. Trans.*, 1812,) led me to regard the colouring-matter of the blood as a *distinct proximate principle* of animal matter, independent of the presence of iron, to which metal its peculiarities were at one time referred by MM. Fourcroy and Vauquelin; and the latter verified my conclusions in the above-quoted memoir. Berzelius, whose labours in animal chemistry are at once refined and extended, has arrived at different conclusions; according to him the crassamentum of the blood consists of

Colouring-matter	64
Fibrin and albumen	36
	100

The colouring-matter, when incinerated, affords a residue consisting of

Oxide of iron	50.0
Subphosphate of iron	7.5
Phosphate of lime with magnesia	6.0
Lime	20.0
Carbonic acid and loss	16.5
	100.0

The iron he regards as contributing to the red colour of the blood, and a hint has been thrown out by Dr. Ure as to the possibility of its being derived from sulphocyanate of iron.

Berzelius examined the solution of the colouring-matter obtained by washing the coagulum, deprived of its serum, in water.

The strong filtered aqueous solution, thus obtained, is dark brownish-red, and becomes brighter by dilution: evaporated at 100°, it leaves a dark residue, soluble in water, but a boiling-heat changes, and renders it insoluble. Chlorine darkens the concentrated solution, and then gradually destroys its colour: alcohol coagulates and renders it insoluble: the acids generally decompose it. Acetic acid heightens the colour of the solution of hæmatosyn, but does not precipitate it: on neutralizing the acetic acid by potassa, the hæmatosyn is precipitated. Weak alkaline solutions act nearly similarly. Sulphuretted hydrogen renders the solution of hæmatosyn first violet, then green, and the red colour is not restored either by alkali or acid. Hæmatosyn is thrown down of a *red* colour by acetate of lead, sulphate of zinc, and corrosive sublimate; and *brown* by nitrate of lead, of silver, and of copper, and by chlorides of gold and of platinum.

The experiments of Dr. Stevens and of Mr. P. Squire, have further illustrated the peculiar nature of hæmatosyn. One of its most striking characters is the change of tint which it apparently suffers by the action of air, and which is well seen in the exposure of venous blood to the action of air, or of oxygen. The colouring-matter of the blood is also rendered florid and brilliant, even when in its blackest venous state, by almost all neutral salts; with sulphate of soda, for instance, or with nitrate of potassa, the effect is extremely striking. Acids, and alkalis, generally render the hæmatosyn black; tartaric, citric, and even carbonic acid produce this effect: they exert more or less solvent power over it, and their solutions are dingy, and often nearly black, by reflected light, but of a peculiar green tint by transmitted light, the intensities of these colours depending upon their states of dilution. Acid salts, and basic salts, act more or less as free acids or alkalis. In neutrosaline solutions, on the other hand, hæmatosyn is insoluble, and if its dark-coloured acid and alkaline solutions be so mixed as accurately to neutralize each other, the hæmatosyn falls, and aquires a florid tint. To observe the action of acids, alkalis, and salts, upon hæmatosyn, to the utmost advantage, the blood should not be suffered to coagulate, but received, whilst flowing, into the acid, alkaline, or saline solution. These facts have been applied by Dr. Stevens to explain the changes of colour which blood suffers in passing from the venous to the arterial state. (*London Medical Gazette*, April, 1834.) He shows, that venous blood contains carbonic acid, and that it gives it off when drawn from the arm into a vessel filled with hydrogen, all contact with air or oxygen being carefully avoided, so as to preclude the formation of carbonic acid by the union of carbon in the blood with the oxygen of the air: that this carbonic acid blackens the hæmatosyn, and that its red colour is restored by its removal, when the saline matters of the blood render it florid: that the change of arterial to venous, or of florid to black blood, occurs in the extreme ramifications of the vessels, or in their capillary anastomoses, for the blood is arterial in the extreme arteries, and venous in the extreme veins: Dr. Stevens also infers that arterial blood contains atmospheric air, or air more abundant in oxygen than that of the atmosphere; and that the removal of the carbonic acid in the lungs is effected by a peculiar attractive power of oxygen for carbonic acid, taking place through the membrane of the lungs; he concludes, and adduces satisfactory experiments in proof of the conclusion, that the change of venous into arterial blood, is not the result of the absorption or combination of oxygen, but of the loss or abstraction of carbonic acid by or from the black blood; the *blackening* cause being thus removed, the saline matter present becomes efficient as the *reddening* cause; for Dr. Stevens has proved that if the salts be abstracted from the colouring-matter, it retains its black colour, notwithstanding the loss of carbonic acid; and that a piece of highly-florid coagulum becomes black when its salts are washed out, and can only again be rendered florid by the addition of saline matter. All these facts have, of course, important bearings upon the theory of respiration.

To the statement which I have now given of the nature and properties of the components of the blood, the following curious facts respecting the *odour* of different kinds of blood have been added by M. Baruel. Whilst preparing the colouring-matter of blood according to M. Vauquelin's process, the clot of ox-blood was heated with a large excess of sulphuric acid of moderate strength, on which occasion a strong odour of beef was observed. Some time after, having occasion to operate upon the blood of a man who had taken opium, the fluid was first coagulated by heat, and divided, after which it was boiled with weak sulphuric acid: immediately so strong an odour of the sweat of man was evolved, as to infect the whole laboratory, and render it necessary for the persons to leave the place.

This and the former fact combined, induced M. Baruel to extend his experiments on these subjects, and the following are the results.

i. The blood of each species of animal contains a principle peculiar to each. ii. This principle, which is very volatile, has an odour resembling that of the sweat, or the cutaneous or pulmonary exhalation of the animal from which the blood was taken. iii. In the blood, this volatile principle is in a state of combination, its odour being then insensible. iv. When the combination is broken, this principle is volatilized, when it is easy to recognise the animal to which it belongs. v. In each species of animal, this principle is more decided, or has more intensity of odour in the male than in the female; and in men, the colour of the hair accompanies certain variations in this principle. vi. This principle is in a soluble state in the blood, and may be found, therefore, either in the unaltered blood, or after the fibrine has been removed, or even in the serosity of blood. vii. Of all the means of separating this principle, concentrated sulphuric acid has succeeded best.

To obtain these results, it is only necessary to put a few drops of blood, or the serum of blood, into a glass, to add concentrated sulphuric acid to the amount of one-third or half as much as of blood, and to stir the whole together with a tube; the odoriferous principle is immediately rendered evident. By these means, M. Baruel can readily distinguish the blood from the following sources.

i. That of a man disengages a strong odour of the perspiration of man, which it is impossible to confound with any other. ii. That of a woman, a similar odour, much weaker, and resembling the perspiration of woman. iii. That of the ox, a strong odour of beef. iv. That of the horse, a strong odour of the perspiration of the horse. v. That of the sheep, a strong odour of wool impregnated with the perspiration of that animal. vi. That of the dog, the odour of the transpiration of a dog. vii. That of a pig, the disagreeable odour of a piggery. viii. That of a rat, the bad odour belonging to the rat.

The same result has been obtained with the blood of various kinds of birds, and even with the blood of a frog, which gave the strong odour of marshy reeds, &c., and with that of a carp, which gave a principle smelling like the mucus which covers the bodies of fresh-water fish.

Upon trials made to ascertain whether spots of blood could be distinguished, and referred to their source, M. Baruel found, that to a certain extent, a pretty sure judgment could be given, even after fifteen days or more. The spotted linen is to be cut out, put into a watch-glass, and being moistened with a little water, is to be left for a short time at rest. When well moistened, a little concentrated sulphuric acid is to be added, and stirred about with a tube; then, by respiring near it, the odour may be perceived. M. Baruel is not sure that the distinction could be ascertained after more than fifteen days, and therefore recommends legal officers to allow of no delay in any experiments, which bear upon cases of judicial investigation.

A question has sometimes arisen as to the possibility of preserving blood, with its principal characters either unimpaired or little altered; the following facts will, perhaps, illustrate this point. In the month of May 1818, blood was drawn from the arm into six phials, each holding about two ounces; these were secured by good corks, which were cemented over, and put away in a closet where they remained till May 1833, a period of 15 years. Two of the phials were then opened. The blood was perfectly liquid without any appearance of coagulum; there seemed to have been no extraordinary evolution of gaseous matter, but it exhaled a nauseous and slightly-putrid odour, with a trace of sulphuretted hydrogen. It was of a dark-purple colour, but became florid-red and was coagulated upon the addition of a few drops of solution of corrosive sublimate; it was blackened and coagulated by acids; alcohol also coagulated it; and the action of acetic acid and of ferrocyanuret of potassium, resembled that upon fresh serum. The chief apparent change, was loss of power of spontaneous coagulation. Heat and electricity coagulated it.

Having enumerated the principal facts which bear upon the chemistry of the blood, I shall now subjoin the results of two analyses of it by Lecanu (*Ann. de Chim. et Phys.*, xlviii. 308.)

Water	780.145	785.590
Fibrin	2.100	3.565
Colouring-matter	133.000	119.626
Albumen	65.090	69.415
Fat (crystalline)	2.430	4.300
Ditto (oily)	1.310	2.270
Extractive, soluble in water and alcohol	1.790	1.920
Albumen united to soda	1.265	2.010
Chlorides of sodium and potassium Carbonates, Phosphates, Sulphates of potassa and soda	8.370	7.304
Carbonate of lime and magnesia Phosphate of lime, magnesia & iron Peroxide of iron	2.100	1.414
Loss	2.400	2.586
	1000.000	1000.000

Lecanu has also given the following statement of the comparative analysis of blood drawn from ten men and ten women.

	Males.	Females.
Water	789.32	804.37
Albumen	67.50	69.72
Saline and extractive matter	10.69	9.95
Red globules	132.49	115.96
	1000.00	1000.00

Comparative experiments have been made on the blood of different animals by Prevost and Dumas, by Tiedemann and Gmelin, and by other physiologists and chemists, for the details of which I must refer to their respective works: the general results are, that the globules vary in size and form, and that the components differ somewhat in their relative proportions, rather than in their essential qualities. In all animals the relative proportion of the aqueous to the solid part of the blood is liable to slight fluctuation, even in the healthy state, hence the discrepancies in its specific gravity; it is probable also that the quantitative if not the qualitative composition of the blood varies in different vessels and different parts of the body, hence perhaps, the slight difference observed in blood abstracted by cupping, as compared with that drawn from the arm.

Blood in Disease. We are but imperfectly acquainted with the changes in the composition of the blood which are the result of disease. An abstract of what is known upon the subject, is given by Gmelin, (*Handbuch*, iv.) and by Dr. Turner (*Elements of Chemistry*.) The morbid changes of the blood resolve themselves into those dependent upon excess or deficiency of its usual components, and those in which foreign substances are detected in it; but the composition of the blood is such as to interfere in almost all cases with the nice indications of delicate tests, and the quantities of foreign matters which render the blood diseased in some cases are so small, as to elude very accurate observation. In cases in which the functions of the kidneys are much disturbed, urea is detected in the blood; and where the secretion of the urine is suspended, it is present in considerable quantity, and the source probably of the fatal consequences that ensue from that cause. Prevost and Dumas tied the renal vessels, and extracted the kidneys of a dog, and on the second day after the operation, they obtained no less than 20 grains of urea from 5 ounces of his blood (*Ann. de Chim. et Phys.*, xxxiii. 90.) Urea has also been detected by Dr. O'Shaughnessy in the blood of patients suffering under Cholera, in which disease the renal functions are usually much disturbed. In jaundice, bile, or at least its bitter and colouring-principles, appear occasionally to exist in the blood, and are discernible in the serum. It not unfrequently happens that the serum of the blood resembles whey, or milk and water; and sometimes it resembles cream; but such cases are very rare; these appearances depend upon the presence of fatty or oleaginous matter, which may be separated by agitation with ether. Drs. Traill and Christison procured 1 *per cent.* of fat from opalescent serum, and as much as 5 *per cent.* from serum which had the appearance of milk. (*Edinb. Med. and Surg. Jour.*, April, 1830.) In some nervous fevers of a typhoid character, the blood is said, during the increase of the disorder, to be more aqueous or thin than in health, and gradually to become more dense during its decrease. The state of the blood in Cholera has excited a good deal of attention. The peculiar whitish or whey-like discharge from the bowels, is said to contain albumen, and the salts of the blood with particles of fibrin; the density of the blood itself is above the natural standard, it is of a remarkably dark colour throughout the system, and sometimes viscid, and incapable of coagulation, but at the same time deficient in saline matter. These appearances have been ascribed to various causes. According to Dr. Thomson, the blood in cholera is wholly unsusceptible of the usual influence of the air, and is consequently decidedly altered in its nature. Dr. O'Shaughnessy however found, that it did become florid when agitated with air, and that it emitted carbonic acid gas. Dr. Stevens ascribes the appearances to deficiency in saline matter, and successfully treated such cases, not only by the administration of solutions of common salt and of chlorate of potassa, but by the actual injection of solution of salt into the veins. Dr. Turner observes, that the most correct opinion perhaps is, that the blood of persons in cholera, in consequence of deranged arterial action, circulates sluggishly, and is therefore imperfectly arterialized, and that the dark colour may arise from that cause, independent of any diminution of saline matter, and may disappear, from an improved circulation, without the administration of salt; although there is no doubt that loss of saline matter increases the dark tint of the blood, and prevents it from acquiring the arterial colour. The secretion of a large quantity of saline fluid by the intestines in these cases, the decided deficiency of salts in the blood, and the relief afforded by restoring saline matter to the system, are however strong points in favour of Dr. Stevens's views. The substance ejected from the stomach in the last stage of yellow fever, and known under the name of *black vomit* is blood blackened and coagulated by the free acid of the stomach.

DETECTION OF BLOOD. It is occasionally important in juridical inquiries, to distinguish between stains upon metal and linen arising from blood, and those from other sources. Orfila has given some useful information upon this subject.

Blood-stains on Steel. When the blade of a knife is stained by blood, it is *red* when the layer is very thin, but *brown* if thicker: heated to about 80°, the blood-spot peels off, leaving the steel tolerably clean; no such appearance arises from common rust, but something like it may be produced by the juice of fruits; in that case the blood-spot may be distinguished from that of vegetable juices, by collecting the portion which scales off, and heating it in a bit of glass tube closed at one end; it exhales the odour of animal matter and ammonia, and the latter may be recognised by its *alkaline* reaction on test-paper: any of the vegetable stains would, under such circumstances exhale *acid* fumes; and mere rust would either give out nothing, or at all events, the slightest possible trace of ammonia. Where it is practicable, the following process is more exact; the stained steel is immersed in water; the hæmatosyn and some albumen gradually dissolve, and leave the fibrin on the blade, from which it may be removed by the nail; red streaks form in the water, which becomes red at bottom: divide this red part into several portions; to 1 add chlorine; it becomes green, then colourless, and then deposits white flakes. To 2 add ammonia, which does not alter the colour when from blood, but if from any ordinary dye-stuff, it becomes purple. Into 3 drop nitric acid; it becomes pale-gray. Into 4 a drop or two of infusion of galls; it does not alter the colour, but occasions a slight cloud. Heat 5 till it boils, when it either deposits flakes, or becomes opalescent. Of these tests, nitric acid and infusion of galls are the most delicate; should rust of iron have mingled itself with the liquid, it may be separated by filtration.

Blood-stains on Linen, &c. Suspend the piece of linen in a little water; the fibrin remains upon it, and may be detected by the evolution of ammonia, if linen or cotton, on the application of a sufficient degree of heat, in a small tube; but the hæmatosyn and some albumen are dissolved or extracted; test the coloured solution as above directed. Should the blood have coagulated upon one piece of linen, and then have gone through, so as to discolour another, no fibrin will be found on the latter. It is possible that a solution of madder, or some such colouring-matter, in a serous or albuminous liquid, might lead to deception; but in this case the stain upon the linen would not be so easily removed by water, and the red solution would become yellow by acids, and violet by alkalis: a mixture of serum and the red of madder is rendered yellow, and does not remain red, on adding infusion of galls.

§ II. MILK.

This fluid, secreted by females of the class *mammalia* for the nourishment of their young, is a white, translucent, aqueous emulsion, containing oil, curd, a species of sugar, mucus, salts, and a free acid*, so that fresh milk slightly reddens litmus. Cows' milk has been principally examined. When carefully evaporated, it leaves from 10 to 12 *per cent.* of residue, but many circumstances interfere with this average. The specific gravity of skimmed milk is 1.033; that of cream 1.024: they consist, according to Berzelius, of

Skimmed Milk.	
Water	928.75
Caseous matter or curd, with a trace of butter	28.00
Sugar of milk	35.00
Muriate and phosphate of potassa	1.95
Lactic acid, acetate of potassa, and a trace of lactate of iron	6.00
Earthy phosphates	0.30
	100.00

Cream.	
Butter	4.5
Curd	3.5
Whey	92.0
	100.0

These can, of course, only be regarded as the average quantities, for, to say nothing of the different density of the milk of different breeds of cows, it varies in the relative proportion of its solid contents at different periods after the birth of the young†; and also with the food of the animal. Subtracting the curd from the contents of milk, the residue constitutes *whey.*

Cream arises from the gradual separation of the lighter suspended matters, and the shallower the vessel, the sooner it separates. When milk is kept for 5 or 6 days at the temperature of about 33°, it evolves nearly the whole of its cream; the residue looks like milk and water. By *churning*, cream is separated into *butter* and *butter-milk*‡; during this process, the temperature of the cream is slightly elevated, a little oxygen is absorbed, and acid produced; but this change is not essential to the separation of the butter, which takes place when air is excluded.

Butter is an oily matter, retaining, in its ordinary state, a little curd and whey; it liquefies at 98°; if melted in hot water, washed, strained, and then allowed to concrete, its impurities are separated; it is less apt, in this state, to grow rancid. 100 parts of alcohol, of .822, dissolve 3.42 of butter. Butter is easily saponified, requiring for the purpose not more than 0.4 of hydrated potassa: it yields 88.5 *per cent.* of concrete fixed acids, in which a little stearic acid, 11.85 glycerine, and three distinct volatile acids, are included. Butter also includes three distinct species of fatty matter: namely, a stearin, an elain, and a third substance, *butyrin*, which produces the volatile acids of its soap. (Chevreul.) The relative proportions of these fats vary, whence the varying consistency of butter. The *stearin of butter* may be obtained by expression, or by deposition from its hot alcoholic solution; it is white, crystalline, and fusible at 112°. 100 parts of boiling alcohol, of 0.822, dissolve only 1.43 parts of it: when saponified, it yields 0.945 of fat-acid, fusible at 112°, 0.072 glycerine, and traces of volatile acids. The *elain* of butter is very difficultly separable from butyrin: Chevreul endeavoured to obtain it by keeping purified butter for a long time at a temperature of about 70°; the elain and butyrin gradually liquefied, and were poured off from the stearin in the form of an oil, specific gravity = 0.922 at 66°. 100 parts of boiling alcohol, of 0.822, dissolved 6 parts. Digested for 24 hours with anhydrous alcohol at 66°, it yielded a solution, which, when poured off from the residue, and distilled in a water-bath, left a sour oil, smelling of butter, and consisting of butyrin with a little elain: the acid was abstracted by washing with a little magnesia and water, when the butyrin remains as an oil which congeals at about 32°. It dissolves in all proportions of boiling alcohol, with this peculiarity, that the solution of 2 butyrin in 10 alcohol becomes turbid as it cools, whilst 10 of butyrin in 12 of alcohol remains clear. The alcoholic solution gradually becomes sour. Butyrin is easily saponifiable: its fat-acids begin to congeal at 90°, but are not perfectly concrete till cooled to 62°.

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* This acid is the *lactic acid.* (p. 1128.) It is abundantly generated during the spontaneous changes which milk undergoes in becoming *sour.*

† When the glands begin to secrete milk, it is at first very different from what it becomes afterwards, and has been termed *colostrum;* it is then more saline than perfect milk, and, in the cow, yellow, thick, and sometimes streaked with blood; it only contains traces of butter, and coagulates, when heated, like a serous secretion: it gradually acquires the characters of perfect milk: it easily putrefies, without becoming sour.

‡ According to Chevreul, butter-milk contains *butyric* acid.

When butyrin, freed from its associated stearin and elain, is saponified, it yields three distinct acids, termed, by Chevreul (*Recherches sur les Corps Gras*), *butyric*, *caproic*, and *capric* acid.

1. Butyric Acid. To obtain this acid, 5 parts of *butyrin* are saponified by 2 of hydrate of potassa; the resulting soap is dissolved in a large proportion of water, and decomposed by an excess of tartaric or of phosphoric acid; the liquid portion is then separated by filtration from the precipitated stearic and oleic acids, and subjected to distillation, when the three above-named acids, being volatile, pass over with the water. The distilled product is saturated by baryta, and gently evaporated to dryness. The residue consists of butyrate, caproate, and caprate of baryta: it is to be decomposed by concentrated phosphoric acid, which separates the three fat-acids in the form of an oily liquid, and the portion which remains with the barytic salt may be abstracted by ether, and obtained either by distilling off the ether at 102°, or by its spontaneous evaporation. The oily mixture of the three acids is then agitated with its weight of water, which dissolves the butyric acid. The oily residue is then repeatedly washed with water, by which the caproic acid is dissolved, and the capric acid remains. The three acids being thus separated, should each be saturated by baryta, and the resulting salts crystallized. 100 parts of the butyrate of baryta are then decomposed by 63.36 parts of sulphuric acid diluted with its weight of water; the butyric acid, which separates, is then decanted off and distilled by a gentle heat; it is then mixed with its weight of powdered chloride of calcium, and, after some days, again distilled by a gentle heat. The butyrate of baryta may also be decomposed by the addition of 1.32 parts of phosphoric acid, specific gravity = 1.12: the acid is then separated by decantation, and by agitation with ether.

Butyric acid is a limpid, colourless, inflammable liquid, resembling a volatile oil; it does not congeal at 15°; it boils at a temperature somewhat above 212°, and volatilizes without decomposition. Its specific gravity is 0.9675 at 50°. It has a sour smell resembling that of rancid butter, and a pungent and slightly-sweet taste: it leaves a white spot upon the tongue, and a greasy stain on paper, which gradually evaporates. It mixes in all proportions with water, but the presence of other acids diminishes its solubility. The density of a mixture of 2 parts of butyric acid and 1 of water is = 1.00287. Butyric acid apparently dissolves without decomposition in sulphuric and nitric acid. In combination with bases, it forms *butyrates*, which, when dry, are inodorous, but when moist smell strongly of butter. When decomposed by heat, they yield carburetted hydrogen and carbonic acid, and an aromatic oil which is not acid: the residue is carbonaceous. The neutral butyrates are soluble, but many of them lose a part of their acid during evaporation. Butyric acid is composed of

				Chevreul.
Carbon	8	48	62.34	62.82
Hydrogen	5	5	6.49	7.01
Oxygen	3	24	31.17	30.17
Anhydrous butyric acid	1	77	100.00	100.00

In its ordinary state, the acid consists of 1 atom of anhydrous acid + 1 atom of water, which it throws off when it combines with oxide of lead: hence we have the formulæ

$(8\,car + 5\,h + 3\,o)$ or but' = anhydrous butyric acid,
$(8\,car + 6\,h + 4\,o)$ or $(but' + q)$ = hydrated butyric acid.

Butyrate of Ammonia. ($A + but'$.) Butyric acid, by absorbing ammoniacal gas, first forms a crystallizable compound, which, by further absorption, produces a liquid, and this afterwards concretes into a mass of acicular crystals.

Butyrate of Potassa ($P + but'$) has a sweetish buttery taste, and is deliquescent and imperfectly crystallizable; 100 parts of water, at 60°, dissolve 125 of this salt, and the solution combines with a large additional proportion of acid.

Butyrate of Soda ($S + but'$) is less deliquescent than the potassa salt: in other respects its properties are similar.

Butyrate of Lime ($C + but'$) forms acicular crystals, of which 17 parts are soluble in 100 of water. This salt is less soluble in hot than in cold water, so that the cold solution concretes when heated: this effect is well observed in a tube, in which the hot and solid hydrated salt liquefies when plunged into cold water.

Butyrate of Baryta. ($B + but'$.) This salt crystallizes in flat prisms, of a greasy lustre, and a buttery and alkaline taste: it restores the blue of reddened litmus. 100 parts of water at 50° dissolve 36 of this salt; it is a little soluble in anhydrous alcohol, and unchangeable in the air: in *vacuo* it loses 2.25 *per cent.* of water without becoming opaque.

Butyrate of Strontia ($Str + but'$) resembles the salt of baryta, but is less soluble.

Butyrate of Lead ($Pl + but'$) forms small silky crystals; it easily loses acid during evaporation, and forms a tribasic salt.

Butyrate of Copper ($Cu + but'$) forms transparent eight-sided prisms. Its solution at 212° deposits a blue powder, which soon becomes brown.

2. Caproic Acid is obtained by the decomposition of 100 parts of *caproate of baryta* by 29.63 of sulphuric acid, diluted with its weight of water; it is digested with chloride of calcium, and distilled. It is a very inflammable limpid oil, of an acrid acid flavour, leaving an impression of sweetness, and smelling like sour perspiration. Its specific gravity is 0.622 at 78°; it does not congeal at 15°. It boils above 212°, and evaporates gradually in the air. Water at 42° scarcely dissolves 1.04 *per cent.* Anhydrous alcohol dissolves it in all proportions.

Caproic acid, in anhydrous combination, consists of

				Chevreul.
Carbon	12 . .	72 . .	68.57 . .	68.33
Hydrogen	9 . .	9 . .	8.57 . .	9.00
Oxygen	3 . .	24 . .	22.86 . .	22.67
Anhydrous caproic acid	1	105	100.00	100.00

The liquid acid consists of 1 atom of anhydrous acid + 1 atom of water ($105 + 9 = 114$) so that we have the formulæ

$({}_{12}car + {}_{9}h + {}_{3}o)$ or $capro' =$ anhydrous caproic acid,
$({}_{12}car + {}_{10}h + {}_{4}o)$ or $(capro' + q) =$ hydrated caproic acid.

Caproates. These salts smell and taste like the acid; they exhale an aromatic odour when decomposed by heat. Their solubility is intermediate between that of the butyrates and caprates. *Caproate of potassa* forms a very soluble gelatinous compound, which becomes opaque when heated. *Caproate of lime* crystallizes in quadrilateral plates, soluble in twice their weight of water. *Caproate of baryta*, when crystallized at 65°, forms hexangular tables; at 85° its crystals are acicular. 100 parts of water at 50° dissolve 8 of this salt. It is fusible at a moderate heat.

3. Capric Acid. 100 parts of the *caprate of baryta* are decomposed by 47.5 of sulphuric acid, diluted with its weight of water; or by 83.6 of vitrified phosphoric acid dissolved in 240 parts of water. The capric acid is distilled after having been digested upon chloride of calcium.

Capric acid forms small acicular crystals, which fuse at about 65°, at which temperature its specific gravity is 0.910. It may be distilled, without decomposition, at a little above 212°. Water at 65° dissolves scarcely a thousandth of its weight of capric acid, but alcohol dissolves it in all proportions. Its odour partakes of that of the goat.

Capric acid consists of

				Chevreul.
Carbon	18 . .	108 . .	74.0 . .	74.00
Hydrogen	14 . .	14 . .	9.6 . .	9.75
Oxygen	3 . .	24 . .	16.5 . .	16.25
Anhydrous capric acid	1	146	100.0	100.00

The crystallized acid includes 1 atom of water ($146 + 9 = 155$), hence the formulæ

$({}_{18}car + {}_{14}h + {}_{3}o)$ or $cap'. =$ anhydrous capric acid,
$({}_{18}car + {}_{15}h + {}_{4}o)$ or $(cap' + q) =$ hydrated capric acid.

Caprates. The humid caprates have the odour and taste of the acid; exposed to heat, they exhale an aromatic and goaty odour.

Caprate of Baryta requires for its solution 200 parts of water at 67°; it is fusible, and of a bitter, alkaline taste.

It will be remarked that each of the three acids of saponified butyrin include 3 atoms of oxygen in their equivalents; so that in the neutral butyrates, caproates, and caprates, the oxygen in the base is to that in the acid as 1 to 3.

Curd of Milk. Caseum. Lactalbumen. This, which is the coagulable or albuminoid principle of milk, may be separated by adding dilute sulphuric acid to skimmed milk, which forms a white coagulum, or *sulphate of caseum*; this is washed to deprive it of whey, and mixed and digested with carbonate of lime or baryta; the acid is thus abstracted by the earthy base, and the free caseum dissolves in the water, so that it may be separated by filtration; this solution is yellowish, and somewhat viscid; during evaporation it smells like boiled milk, and becomes covered with similar films, which may be successively removed; when dry, the caseum is yellow, and soluble in water, and the solution is coagulated by acids, especially when warm; and when left to itself, it putrefies and smells like old cheese*. The transparent desiccated caseum becomes opaque in alcohol, in which it is sparingly soluble. (Frommherz and Gugert. Schweigger's *Jour.*, L. 72.)

Caseum closely resembles albumen in regard to the action of the acids; the principal difference being, that it is precipitated by acetic acid; the precipitate is re-dissolved by excess of acid, but less easily than albumen or fibrin. The acid solutions of caseum are precipitated by ferrocyanuret of potassium. The alcoholic solutions of caseum are not precipitated by acids; and its acid compounds, which are insoluble in water, are soluble in alcohol. Caseum combines with the alkalis and alkaline earths, and its aqueous solution is precipitated by all those salts which throw down albumen, and also by tannin.

Caseum, like albumen, exists in the liquid and coagulated form; but its coagulation is not effected by boiling, but by the action of *rennet*, which is the inner coat of the calf's stomach after it has been washed in hot water. How this operates is unknown; but a similar coagulating power resides in the stomachs of most, if not all, animals. Berzelius put 1 part of the inner membrane of the calf's stomach, after having been well washed and dried, into 1800 of skimmed milk, gradually heated up to 122°, and kept at that temperature till fully coagulated; he then took it out, washed, and again dried it; it had only 6 *per cent.* in weight.

Cheese is a mixture of coagulated caseum with more or less butter; its various qualities depend upon a variety of causes, partly connected with the properties of the milk employed, partly upon occasional additions to it, and peculiarities of manipulation; there are, however, two leading varieties dependent upon the absence and presence of butter; the former is a poor and comparatively hard and tasteless cheese, little prone to change, and when heated, shrivels up like horn; the latter is rich, fusible, and when toasted, becomes soft and viscid, entering into a state of greasy semifusion. English cheese is frequently coloured by annotta, and often contains a preposterous quantity of salt, added partly to preserve it, and partly to increase its weight. The flavour and texture of cheese alters considerably by age; and if originally moist, it gradually passes into a peculiar state of putrefaction, the products of which have been examined by Braconnot. (*Ann. de Chim. et Phys.*, xxxv., 161.) He found that curd covered with water, and kept at a temperature of about 75°, underwent complete putrefaction in about a month. The liquid was then filtered off, smelt putrid, and, when evaporated to the thickness of honey, concreted into a granular mass, part of which was soluble in alcohol; the insoluble residue is what Proust (*Ann. de Chim. et Phys.*, x., 40,) termed *caseous oxide*, and the soluble portion, *caseate of ammonia.* Braconnot dissolved the caseous oxide in water, filtered through animal charcoal, and then obtained a colourless solution, which, by spontaneous evaporation, yielded a crystallized product: to this he gives the name of *aposepedin*, (from απο, and σηπεδων, *product of putrefaction.*)

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* Braconnot conceives that dried caseum may be used as an article of food; and that with water, butter, and sugar, it might form a good substitute for milk in long voyages.

Aposepedin is a friable crystalline substance, inodorous, slightly bitter, heavier than water, burns without residue, and when heated in a tube open at both ends, it rises in vapour, which deposits itself as a crystalline sublimate. Heated in a retort, this volatilization does not ensue, but it is decomposed, yielding concrete oil, and a liquid containing carbonate and hydrosulphuret of ammonia. It is very sparingly soluble in alcohol, and deposited from its boiling solution as it cools in the form of a light powder like magnesia; nitric acid decomposes it; muriatic acid dissolves it, and the evaporated solution concretes on cooling. Its aqueous solution yields a flocculent precipitate with infusion of galls, soluble in excess of the precipitant; subacetate of lead also throws down a white precipitate.

The supposed solution of *caseate of ammonia*, above-mentioned, contains, according to Braconnot, aposepedin, acetic acid, animal extractive, a resinous substance, several salts, and a peculiar *oil*, which is extremely pungent, and identical with that which is generated in old cheese, and gives to it its acrimony. Oleic and margaric acids, margarate of lime, and the acids of butyrin are contained in the insoluble residue remaining upon the filter. The composition of aposepedin has not been ascertained; it probably contains a large proportion of nitrogen, and from its blackening effect upon silver, and the products of its destructive distillation, sulphur seems to be one of its elements.

The equivalent of caseum, or lactalbumen, cannot be determined, so that its atomic constitution must be hypothetical; it is given as follows by Gmelin, in reference to Gay Lussac's analysis:

				Gay-Lussac and Thenard.
Carbon	7	42	60.87	59.781
Hydrogen	5	5	7.25	7.429
Oxygen	1	8	11.59	11.409
Nitrogen	1	14	20.29	21.381
Caseum	1	69	100.00	100.000

The carbonaceous residue of caseum affords, when incinerated, about 6 *per cent.* of phosphate of lime, an ingredient in milk, which, as Berzelius remarks, forms an important feature in respect to the nourishment of young animals, who require it for the formation of bone.

Whey. Sugar of Milk. When the butter and curd of milk are abstracted, there remains a pale yellowish opalescent fluid, termed *whey*, which, when evaporated, deposits a crystallized substance called *sugar of milk*. Sometimes whey is evaporated to dryness, and the residue used as an article of food; in Switzerland, sugar of milk is an article of commerce; it forms crystallized cakes or masses of a prismatic and lamellar fracture; it is slightly sweet, and gritty: its sp. gr. = 1.543. It contains 12 *per cent.* of water, which may be evaporated by careful fusion, after which it concretes into an opaque white mass. Its water is also expelled by fusion with oxide of lead. It is slowly soluble in 3 parts of hot and 6 of cold water, very sparingly soluble in alcohol, and insoluble in ether. It is not susceptible of vinous fermentation. It is convertible, like starch, into granular sugar, by boiling with a very dilute sulphuric acid. Nitric acid converts it into malic, oxalic, and *mucic* or *saclactic acid*, (p. 897.) Caustic potassa converts it into a brown bitter substance. When digested with oxide of lead and water, sugar of milk forms a soluble and an insoluble compound; the insoluble and anhydrous combination consists of 63.5 oxide + 36.5 sugar of milk; in this compound, the oxygen, according to Berzelius, in the oxide, is to that in the sugar as 1 to 4, whence the following estimate of the equivalent and atomic composition of this organic product:

				Berzelius.
Carbon	5	30	45.45	45.267
Hydrogen	4	4	6.06	6.385
Oxygen	4	32	48.49	48.348
Anhydrous sugar of milk	1	66	100.00	100.000

The *crystallized* sugar of milk consists of

				Berzelius.
Anhydrous sugar of milk	1	66	88	87.667
Water	1	9	12	12.333
Crystallized sugar of milk	1	75	100	100.000

Or,

				Berzelius.	Gay Lussac and Thenard	Prout.
Carbon	5	30	40.00	39.474	38 825	40.00
Hydrogen	5	5	6.67	7.167	7.341	6.67
Oxygen	5	40	53.33	53.359	53.834	53.33
Crystallized sugar of milk	1	75	100.00	100.000	100.000	100.00

Human Milk. The statements respecting the composition of human milk are much at variance, arising probably in part from the difficulty of obtaining it in sufficient quantity for analysis, and partly from its mutability in regard to the relative proportions of its component parts. L. Gmelin and Berzelius have each given the details of the experiments which have been made upon it. Its sp. gr. appears to vary between 1.020 and 1.025, or a little higher: its solid contents, according to Meggenhofen, vary between 11 and 12.5 *per cent.*, and its albumen or caseum is said to furnish soluble combinations with acids, so that it is not coagulated by them. Of fifteen samples, only three were coagulated by acetic and muriatic acids; but they were all coagulated by *rennet:* this is an important fact, as establishing the distinct action of rennet from that of acids. The following are the results of three of Meggenhofen's analyses:

	I.		II.		III.
Butter, acids, and salts . .	9.13	. .	8.81	. .	17.12
Sugar of milk and salts . .	1.14	. .	1.29	. .	0.88
Curd coagulated by rennet .	2.41	. .	1.47	. .	2.88
Water	87.25	. .	88.35	. .	78.93

The extraordinary proportion of butyraceous matter in III., shows the uncertainty of composition in this secretion: indeed, in all the above cases the quantity of butter appears to have been excessive, for Payen's results, which, in regard to the total amount of solid matter, agree with Meggenhofen's, do not give an average of more than 5.2 *per cent.* of that ingredient.

Asses' Milk has a specific gravity = 1.023 to 1.0355, it yields a light white butter, which soon grows rancid: the curd is more difficultly separable than from cow's milk, but the whey is clearer, and contains more sugar of milk. It contains 2.9 cream, 2.3 caseum, 4.5 sugar of milk (*per cent.*): and, according to Van Stiptrian Luiscius and Bondt, it is susceptible of vinous fermentation.

Mares' Milk has a specific gravity = 1.034 to 1.045; it yields little cream, but a large proportion of sugar of milk; a vinous liquor is obtained by the fermentation of its whey, known in Tartary under the name of *koumiss.*

Goats' Milk is of a specific gravity = 1.036; its goaty odour is stronger from dark than from white goats; it yields much cream and butter, and this, besides the usual acids, yields a peculiar one, called by Chevreul *hircic acid,* which gives it its characteristic odour: its caseum is also abundant, and the whey easily pressed out of it. It contains in the 100 parts 4.08 butter, 4.52 caseum, 5.86 residue of the whey, 85.50 water (Payen); 7.5 cream, 4.56 butter, 9.12 caseum, 4.38 sugar of milk, (S. Luiscius and Bondt.)

Sheep's Milk, of the specific gravity of 1.035 to 1.041, yields much cream, the butter of which is semifluid, and easily becomes rancid: the butter is difficultly separable from the curd, so that the cheese which it yields is rich and greasy. It affords 11.5 cream, 5.8 butter, 15.3 caseum, 4.2 milk-sugar, *per cent.*

It has not been ascertained how far all milk is susceptible, under favourable circumstances, of vinous fermentation, nor whether any common sugar is present in the milk which undergoes that change; milk-sugar and water with a ferment, will not produce a vinous liquor: Scheele found that the addition of an ounce of brandy to a quart of milk caused it to undergo acetous fermentation, and that in a month it yielded good vinegar when poured off the curd, and contained no lactic acid.

At temperatures above 55°, milk absorbs oxygen, and becomes sour; between 68° and 75°, this takes place in a few hours, and the milk then curdles when boiled; but Gay Lussac found that fresh milk heated every other day, or in summer every day, up to 212°, might be kept for months without spoiling. Milk, which has become sourish, may be recovered by heating it with a little carbonate of potassa or soda, sufficient to neutralize its acid. When milk grows sour, the lactic acid which is produced combines with the curd, and the combination may be decomposed (as stated in regard to the *sulphate of caseum*) by alkalis, or alkaline earths.

The influence of food upon the milk is well known by the varieties of taste, colour, and odour, which are so produced. From some of the *Euphorbiæ*, and from the *Gratiola officinalis* it is said to acquire a laxative power. Madder, saffron, the flowers of *Ranunculi*, and many other colouring-matters, communicate to it their tints. The volatile oils of the *didynamiæ* affects its odour. Various medicines apparently affect the properties of the milk, as indicated by its effects upon the infant; and the influence of affections of the mind upon the secretion are often very obvious; these subjects, however, have as yet engaged but little of the attention of the chemist.

§ III. BILE. Biliary Concretions.

This important secretion has been laboriously examined by several modern chemists of eminence, among whom we may especially enumerate Thenard (*Mémoires d'Arcueil*, i.), Berzelius (*Lehrbuch der Thier-chemie.*, and *Med. Chir. Trans.*, iii.), Tiedemann and Gmelin (*Uber die Verdauung*, Essay on Digestion), and Frommherz and Gugert (Schweigger's *Journal*, v. 1.) Their results, however, are so much at variance, that it is impossible to draw any general conclusions from them respecting the real nature and chemical components of the bile; these discrepancies seem partly to arise from the extreme facility with which chemical agents react upon this secretion, so that many of the supposed *educts* or component parts, which have been enumerated, are probably *products* of the different operations to which it has been submitted, or at all events, modifications of its true proximate elements: it has been therefore well observed by Berzelius, that our present chemical knowledge of the nature of bile can only be considered as a foundation for the more extended and satisfactory researches of future experimentalists. I shall here endeavour to select some of the least disputable and most important facts respecting the chemical properties of the bile, remarking at the outset, that the indications of reagents upon different specimens of bile are apt to vary, and that their action is often much modified by temperature, quantity, and the mode in which they are used.

There always appears to be mixed with bile a variable proportion of *mucus*, probably derived from the gall-bladder and its ducts, and not, therefore, a true component of the secretion: this gives the bile its viscidity, and often seems in some way to modify its other characters: in general, however (*ox-gall*), it is a green liquid, varying somewhat in tint, of a peculiar odour, a bitter and nauseous taste, and a specific gravity fluctuating between 1.020 and 1.030. It does not coagulate when heated, and although it may possibly contain albumen, or something very like it, it is not immediately coagulated by alcohol or by dilute acids. The relative proportion of solid matter obtained by the evaporation of bile, is between 8 and 10 *per cent.* By means of acetic acid, the mucus which is mixed with the bile may to a great extent be separated. In the *mammalia*, generally, the bile exhibits nearly the same characters; and in birds and fishes its components seem to be the same, but rather more dilute in the former, and more concentrated in the latter: it is always alkaline, from the presence of soda, apparently in the same state of combination as it exists in the serum of the blood. When bile is evaporated very carefully to about half its bulk, and alcohol added, (in the proportion of about four parts to one of the evaporated bile,) a coagulated matter is thrown down, which has some of the properties of albumen; yet neither solution of corrosive sublimate, nor of ferrocyanuret of potassium, which are such delicate tests of that proximate animal principle in other cases, enables us to detect it in the original bile. Chlorine first renders bile green, and then opaque or milky. Acetate of lead gives no precipitate, but subacetate of lead throws drown a copious curdy substance. When alcohol is added to bile which has been evaporated nearly to dryness, it acquires, when filtered off, a brownish-green colour and bitter taste; when evaporated, it leaves a residue which is almost totally soluble in water; and in this aqueous solution, dilute sulphuric acid slowly throws down a gray substance, which appears to be a compound of the acid and the bitter principle of the bile; when it has been washed with water (in which it is not soluble), it dissolves in alcohol, and if the sulphuric acid be then separated from it by carbonate of baryta and filtration, the filtered solution leaves on evaporation a green, transparent, bitter residue, which appears to be the characteristic principle of the bile, and which Berzelius calls *Gallenstoff.* As thus obtained, it is not quite free from foreign matters, and ether digested upon it takes up a little fatty matter; indeed, when bile, concentrated by evaporation, is agitated with ether, and the latter, after having separated upon the surface, is poured off and evaporated, it always leaves traces of a fatty substance, probably identical with *cholesterine.* The purified bitter residue, to which we have just adverted, is apparently the *picromel* of Thenard; it has a bitter, pungent, and sweetish taste, is inflammable, deliquescent, soluble in water and alcohol, but insoluble in ether; its solution is precipitated by many acids, (not by acetic or phosphoric,) and the precipitate is nearly insoluble in water, of a greenish colour, resinous appearance, and fusible at 212°. This precipitate (consisting of picromel combined with the acid used to throw it down) dissolves in alcohol, and is again thrown down by water: it dissolves in solution of acetate of potassa, the alkali of which combines with the acid of the precipitate, whilst the acetic acid unites to the picromel to form a soluble acetate. Picromel dissolves in weak alkaline solutions apparently without decomposition.

It is possible, from the above characters, that certain combinations of picromel (by which I mean Berzelius's *Gallenstoff*) may have been mistaken for resin, and for albumen, and that it is not improbable that the only true albuminous part of the bile may be in that equivocal state which is often called *mucus*, and which is especially distinguished by being precipitable by acetic acid. Berzelius has suggested an analogy between picromel and the peculiar saccharine matter which is contained in liquorice-root; and in many respects their chemical properties are identical.

In the preceding statement, drawn principally from Berzelius, I have endeavoured to give the simplest view of the analysis of the bile; namely, the separation of its *muco-albumen* by acetic acid or alcohol, and of its *picromel* by precipitation with acids, and subsequent decomposition of the precipitate by carbonated baryta or alkali; its saline contents appear closely to resemble those of the serum of the blood; like which it has an alkaline reaction, due to soda. I have also selected such experiments, as, with me, have invariably succeeded: the following results, therefore, of the analysis of the bile, as given by Berzelius, will now be intelligible:—

Water	90.44
Picromel (Gallenstoff), including fat	8.00
Mucus of the gall-bladder	0.30
Extractive, common salt, and lactate of soda	0.74
Soda	0.41
Phosphate of soda and lime, and traces of a substance insoluble in alcohol	0.11

The details of the other analyses of the bile, as given by the authorities to which I have referred above, would be unintelligible if abridged, and are too voluminous, to be inserted here; and, moreover, I have generally failed in arriving at satisfactory conclusions in my endeavours at a repetition of the various analytical operations which are described; I must, therefore, rest satisfied with giving, in a condensed form, a general statement of their results. According to Thenard, *human bile* contains, water 90.90; yellow bitter resin 3.73; yellow matter generally diffused through the bile (mucus and colouring-matter?) 0.18 to 0.90; albumen 3.82; soda, by which the resin is dissolved, 0.51; phosphate, sulphate, and muriate of soda, phosphate of lime, and oxide of iron, 0.41. Tiedemann and Gmelin give the following as the components of human bile: 1. fat; 2. brown resin; 3. sweet principle of bile; 4. salivary matter; 5. mucus; 6. gall-brown (colouring-matter?); 7. oleic acid, salts, and minute quantities of other substances. Frommherz and Gugert (Schweigger's *Journal*, L. 8) have arrived at yet more complicated results: namely, 1. fat; 2. resin; 3. sweet principle; 4. osmazome; 5. salivary matter (Speichelstoff); 6. caseum; 7. mucus; 8. margaric and other fatty acids, with phosphate, muriate, and sulphate of soda and potassa; and carbonate, phosphate, and sulphate of lime. The above, and other chemists, have published analyses of bile, taken after death in various diseases, but they present nothing very important. Tiedemann and Gmelin's elaborate analysis of *ox-gall* deserves the perusal of all chemists concerned in such inquiries: it contains, according to L. Gmelin, (*Handbuch der Theor. Chem.*, ii., 1012.; Frankfurt, 1829,) a substance not to be found in any other bile, and which he has called *Taurin* or *Gallen-asparagin*: it may be obtained as follows:—Add muriatic acid to ox-gall, and filter; after a few days a fatty matter appears, which is separated by filtration; the filtered liquid is evaporated to a small bulk, when it separates into two parts—a resinous mass, and a sour fluid: the latter, upon further evaporation, yields more resinous matter, and at length crystals of common salt and taurin, which are to be separated, and the latter purified a second time by crystallization. Taurin, when purified, is in prismatic crystals, neither acid nor alkaline, not altered by exposure to air, inodorous, of a peculiar taste, soluble in about fifteen parts of cold water, and nearly insoluble in absolute alcohol; it is fusible, and not decomposed by nitric acid.

In concluding this subject, I must again observe that many of the supposed proximate components of bile are perhaps *products* of the various operations and re-agents to which it has been submitted, and that the analysis of Berzelius, which is the simplest, is probably the most correct: from the uncertain operation of various precipitants upon bile, and from the facility with which the results vary, apparently in consequence of very trifling causes, there seems to be a peculiar tendency in its component parts to undergo hitherto unexplained modifications.

Biliary Calculi, or Gall-stones. These concretions have been especially examined by Gren, Thenard, Fourcroy, and, as to the fatty matter which they contain, by Chevreul, (*Ann. de Chim.*, xcv., 5.) Human gall-stones are, for the most part, composed of a crystalline aggregate of a species of adipocere, or as it has been termed by Chevreul, *cholesterine* (from χολη, *bile*, and στερεος, *solid*), with more or less colouring-matter, muco-albumen, and inspissated bile; they are accordingly of various colours and textures, but generally brittle and friable. Those which are chiefly cholesterine, or, as it should more properly be termed, *cholestearine*, are white and crystalline, and lighter than water; the others are more tough, coloured, and dense; their specific gravities, therefore, vary from 0.803 to 1.06. Their chemical examination may be conducted as follows: They may be powdered, and digested in water to separate the inspissated bile: then boiled in alcohol, and the solution filtered whilst hot; as it cools it deposits the cholesterine, and often retains common fat and its acids in solution. The portion which resists the action of alcohol may be digested in a weak solution of caustic potassa, which takes up colouring-matter and muco-albumen: the solution, supersaturated by acetic acid, deposits these, and the colouring-matter may afterwards be removed by alcohol. Any common albumen may be detected by ferrocyanuret of potassium added to the acetic solution.

Cholesterine separates in white pearly scales from its hot alcoholic or ethereal solution during cooling; it fuses at about 280°, and when heated to about 400°, it sublimes: in the open air it burns like wax. Its ultimate components are 85 carbon, 12 hydrogen, 3 oxygen. It is the most carbonaceous of all the varieties of fat.

The gall-stones of the ox frequently consist chiefly of the yellow colouring-matter of the bile, which is occasionally used by painters, on account of its brightness and durability: it is insoluble in water and alcohol, but readily soluble in weak solution of potassa, from which it is thrown down in green flocks by muriatic acid: nitric acid, cautiously dropped into a solution of this colouring-matter, gives it various shades of green, blue, and red. *A gall-stone from a sow* yielded cholesterin 6.0, resin 45. soda with resin 3.6, mucus, colouring-matter, phosphate of lime and oxide of iron 45.4. (Lassaigne.)

§ IV. SALIVA. PANCREATIC JUICE. GASTRIC JUICE. LYMPH. MUCUS. PUS.

SALIVA has been examined by Berzelius, and more in detail by Tiedemann and Gmelin. (*Uber die Verdauung*.) The principal use of this secretion appears to be to attenuate, and mix with the food during mastication; it is consequently secreted in great abundance during a meal; at other times, only in such quantity as to lubricate the mouth and parts adjacent.

Human saliva is transparent, viscid, and contains an animal matter, frequently termed *mucus*, but its peculiarities have been pointed out by Berzelius, who designates it *salivary matter*. (*Speichelstoff*.) Under the term *mucilaginous extractive*, a similar principle has been found in other animal fluids. The specific gravity of human saliva is 1.0043. It is generally slightly alkaline; sometimes neutral; and in some diseases (intermittent fever and abscess) sour; nitric acid separates from it transparent films. The salts of lead, tin, copper, and mercury, and infusion of galls, yield with it a dense white coagulum; it renders dilute permuriate of iron yellow-red. It loses from 99.1 to 98.81 *per cent.* by evaporation, and leaves a residue = 0.9 to 1.19. The dry *residue* contains fatty matter, with traces of phosphorus, osmazome, sulphocyanate, muriate, and acetate of potassa, (with a little soda,) 31.25. It affords to hot alcohol albuminous matter (caseum?) with a trace of sulphate of potassa, 1.25; salivary matter, with alkaline phosphates, and traces of sulphates and muriates, 20.00; mucus, with carbonate and phosphate of lime, 40.00, (loss 7.5.) By incineration, the dry residue of saliva yields 21.9 *per cent.* of ash, composed of 17.8 carbonate, phosphate, muriate, and a little sulphate of potassa, (with traces of soda,) and 4.5 phosphate of lime, with a little carbonate of lime and magnesia. (Gmelin.) According to Berzelius, the components of saliva are, salivary matter 0.29, mucus 0.14, osmazome with lactate of soda 0.09, soda 0.02, chloride of potassium and chloride of sodium 0.17, water 99.29. By transmitting a current of electricity through saliva I obtained indications of albumen, resembling those with other albuminous fluids. (*Phil. Trans.*, 1809.)

In the saliva of a person suffering under diseased lungs, whose perspiration smelt sour, and whose gastric juice contained much acetic acid, whilst the urine was highly alkaline, Dr. Prout found free acetic acid. (*Phil. Mag.* and *Ann.*, iv., 122.) During mercurial salivation, the specific gravity of the saliva was 1.0038, and contained albuminous flakes = 0.257, mucus 0.367, chloride of sodium 0.090, water 99.286. (Thomson, *Ann.*, vi., 397.)

In a similar case, in which the saliva amounted to two quarts daily, Dr. Bostock found it of a pale-yellow colour and opaque; it deposited, in the course of twenty-four hours, viscid films, and became transparent; it became turbid at 212°, and with muriatic acid and corrosive sublimate it gave an albuminous precipitate: it left, on evaporation, 2 *per cent.* of dry residue. (*Med. Chir. Trans.*, xiii., 73.)

The saliva of the dog and of the sheep have been analysed by Gmelin, and of the horse, by Lassaigne. (*Ann. de Chim. et Phys.*, xix., 176.) The saliva of the sheep contained so much carbonate of soda as to effervesce with acids, and also sulphocyanuret of potassium. Its solid matter amounted to 1.2 *per cent.* That of the dog left 2.51 *per cent.* of solid matter, but yielded only very slight traces of sulphocyanogen. The saliva of the horse afforded 3.5 *per cent.* of solid residue, and deposited carbonate and phosphate of lime.

Salivary Concretions. These are sometimes found in the salivary ducts and glands; they have been repeatedly analyzed, and consist of phosphate of lime, carbonate of lime, &c., and albuminous matter. A calculus from the salivary duct of a woman sixty years of age, was white, friable, specific gravity = 2.30. It contained animal matter 25, phosphate of lime 55, carbonate of lime 15, carbonate of magnesia 1, oxide of iron 2? loss 2. (Bosson.) A calculus from the salivary gland of an ass, contained 91.6 carbonate of lime, 4.8 phosphate of lime, and 3.6 animal matter. (Caventou.) A salivary stone from a horse consisted of 85.52 carbonate of lime, 7.56 carbonate of magnesia, 4.40 phosphate of lime, and 2.48 of animal matter. (Henry, jun.)

Tartar of the Teeth. This term is applied to a deposit formed upon those parts of the teeth which are protected from the cleansing influence of the tongue, and is most abundant in the mouths of persons who speak much, and keep the mouth open, so as to allow of the evaporation of the saliva. It consists of animal matter and earthy phosphates. Berzelius obtained from 100 parts of this substance, salivary matter 1.0, mucus 12.5, earthy phosphates 79.0, animal matter soluble in muriatic acid, 7.5. According to Vauquelin and Laugier it contains, 0.13 insoluble mucus, 0.66 phosphate of lime, with a trace of magnesia, 0.09 carbonate of lime, 0.05 soluble animal matter, 0.07 water.

Pancreatic Juice. This secretion, from a dog, contains, according to Gmelin, albumen, and a substance like curd, a small quantity of mucus and osmazome, (salivary matter?) and a free acid. Its salts resemble those of saliva, excepting sulphocyanates. It afforded 91.72 *per cent.* of water. That from the sheep contained 1.51 substances soluble in alcohol, 0.28 soluble in water, 2.24 coagulated albumen, 96.35 water. The supposed analogy between saliva and the secretion of the pancreas seems, therefore, to be disproved.

Gastric Juice. The extraordinary solvent powers of this secretion, and its property of coagulating milk (and other albuminous liquids?) have been long known, but its chemical nature does not satisfactorily explain these properties. We are indebted to Dr. Prout for the curious discovery of the presence of muriatic acid in this secretion, (*Phil. Trans.*, 1824;) he found it, together with acetic acid, in the gastric juice of the rabbit, hare, horse, calf, and dog, and in the sour matter thrown up by persons suffering from indigestion, a fact also confirmed by Mr. Children. According to Tiedemann and Gmelin, any foreign matter in the stomach excites this acid secretion, but especially stimulating food. The other properties of gastric juice will be mentioned when considering the phenomena of digestion.

Lymph. This term is applied to the fluid which lubricates the different cavities of the body, and which moistens its cellular textures; it sometimes collects in morbid quantity, as in *dropsies*, and is found in the thoracic duct of an animal that has been kept for twenty-four hours without food. The liquid of some vesications seems, chemically speaking, closely to resemble it. It is colourless, transparent, miscible in all proportions with water, does not affect vegetable blues, and is not coagulated by acids or by alcohol. When evaporated to dryness it yields slight traces of albuminous matter.

Its composition, however, in dropsical cases, is liable to much variation, depending probably upon the cause of its accumulation, and the manner in which it has been thrown out. When this has been a very gradual process its characters are those of common lymph; but when rapid, or attended by inflammatory action, it is more abundant in albumen, and sometimes approaches *serum* in its characters and composition—hence dropsical fluids are often very dissimilarly constituted, as far, at least, as regards quantitative composition*.

MUCUS. All animal fluids of a viscid or glairy consistence, and not partaking of the decided characters of albumen, were formerly classed under this term, till Mr. Hatchett, in his valuable essays on animal substances, and especially in his observations on the component parts of membrane, showed the necessity of assigning to it a more definite meaning. Dr. Bostock includes, under the term *mucus*, animal substances which are soluble in hot and cold water; not precipitated by tannin or corrosive sublimate; not gelatinizable; but which are thrown down by subacetate of lead. Fourcroy and Vauquelin improperly compare it to gum. Berzelius remarks, that if the term mucus be restricted to the secretion from what are termed *mucous membranes*, it will include a variety of dissimilar products, and in the paper already quoted, I have shown that the characters generally ascribed to mucus, are in some cases derived from peculiar forms or combinations of albumen.

The secretion which is most appropriately termed *mucus*, is that from the nasal membrane; its properties are amply given by Berzelius. It appears when first secreted to be thin and aqueous, but, subject, from its situation, to the constant action of air, and to evaporation, it gradually thickens. It contains *mucus* (a peculiar animal principle) 5.33, extractive matter soluble in alcohol and an alkaline lactate 0.30, chlorides of potassium and sodium 0.56, extractive matter soluble in water only, with traces of albumen and a phosphate, 0.35, soda combined with the mucus 0.09, water 93,37. Of these components the *mucus* is the only one which is peculiar to this secretion; its properties are defined by Berzelius as follows: it swells and acquires apparent fluidity in water, without being actually dissolved, but gives a ropiness to it when present to a less amount than 1 *per cent.* With pure water of the temperature of 95° this appearance ensues in a few hours, but if the apparent solution be filtered, the mucus remains upon the paper and gradually thickens; it may be repeatedly dried and moistened without material change of properties; it, however, becomes less transparent, yellow, and at length has a purulent appearance. When boiled in water it does not harden and shrink, but becomes tough, and on cooling is found to retain its former characters. When dried, it is yellow and translucent; and subjected to distillation, it yields carbonate of ammonia and empyreumatic oil, and phosphate and carbonate of lime, and a trace of carbonate of soda, are found in the residuary ash. It is soluble in dilute sulphuric acid, and is blackened and decomposed by the concentrated acid. Dilute nitric acid coagulates, and tinges it superficially yellow, after which it swells and becomes viscid as at first: when digested in the acid it is entirely dissolved. Acetic acid coagulates, but does not dissolve it; it, however, acquires a trace of albumen, and consequently becomes cloudy on the addition of ferrocyanuret of potassium. Caustic potassa first renders it more viscid, and then dissolves it. Infusion of galls thickens and coagulates it in all its states.

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* The human *liquor amnii* is ammoniacal and albuminous; it yields copious precipitates with corrosive sublimate and infusion of galls. It is also said to contain benzoic acid and urea. Soda, muriate of soda, and phosphate and carbonate of lime, are also contained in the amniotic fluid; and Dr. Prout found traces of sugar of milk in it. (*Ann. of Phil.*, v., 417.) The solid contents amount to between 2 and 3 *per cent.* The acid described by Buniva and Vauquelin, as peculiar to the *liquor amnii* of the cow, and termed *amniotic acid*, was found by Dzondi to belong to the liquor of the allantois, or to the urine of the fœtus. The *allantoic acid* is obtained by evaporating the allantoic liquid of the fœtal calf: it forms white acicular crystals, sparingly soluble in water, but yielding soluble salts with the alkalis. It consists, according to Liebig, of (5 *car* + 4 *h* + 4 *o* + 2 *n*.) (See also Lassaigne, *Ann. de Chim. et Phys.*, xxxiii., 279.)

PUS. This, and the term purulent *matter*, is applied to the secretion of inflamed and ulcerated surfaces, and its characters are very different according to the circumstances under which it is secreted. When it indicates a healing sore, it has been called *healthy pus*, and has the following properties. It has the consistency of cream, a yellowish colour, and exhibits, under the microscope, the appearance of globules diffused through a fluid. (Home, *On Ulcers*, 2d Edit., p. 13.) Its specific gravity is about 1.030. It does not affect vegetable colours till it has been some time exposed to air, when it becomes slightly sour; it does not easily mix with water, alcohol, or dilute acids. (Pearson, *On Pus*, Nicholson's *Journal*, xxx.) The composition of pus has not been accurately determined, and there is no accurate test by which it can be satisfactorily distinguished from albuminous and mucous secretions, when, as is almost always the case, it is more or less mixed with those animal fluids.

TEARS contain a small portion of albumen combined with soda, muriate of soda, and water. There are also small portions of other salts.

HUMOURS OF THE EYE. The *aqueous* and *vitreous humour* are composed of water holding a minute quantity of albumen and saline matter in solution; the *crystalline lens* also contains more than half its weight of water, the remainder being a peculiar albuminous substance with traces of saline substances.

SYNOVIA is the fluid which lubricates the surfaces of joints. It contains, according to Mr. Hatchett (*Phil. Trans.*, 1799,) a small portion of phosphate of lime, and of phosphate of soda and ammonia; the animal principle appeared to be albumen.

In *oysters*, in the vertebral fluid of the *Squalus maximus*, and in *frog-spawn*, are contained modifications of *mucus;* that of frog-spawn is very remarkable, from the extent to which it swells up in water, forming a very bulky and transparent jelly, so that a piece not larger than a pea of the recently-emitted gelatinous matter that envelops the ova of the frog, will gradually absorb and gelatinise 8 or 10 ounces of water.

§ V. URINE. Urea. Uric Acid. Urinary Calculi.

Urine. This secretion carries off several substances from the blood, which may be termed excrementitious, and which would be injurious if retained; these substances are, for the most part, abundant in nitrogen. The *quantity* of urine which is formed, or secreted, in the ordinary and healthy state of the system, is very variable, depending upon the quantity of liquids taken into the stomach, the extent of perspiration, and apparently, in many cases, upon the dry or humid state of the atmosphere, a cause by which the abstraction of moisture by the skin is greatly modified. Between 30 and 40 ounces may, perhaps, be considered as the average quantity of the urine voided by a healthy person, living upon ordinary diet, in the course of each 24 hours.

But the *quality* of the urine is no less variable than its quantity; so that its density is perpetually varying; sometimes its specific gravity scarcely exceeds that of water; at others, it rises to 1.030, or even in some diseased states, to 1.040; that which is voided in the morning by a person who has eaten and drunk moderately of usual diet is usually a little on one side or other of 1.020.

Recent healthy urine always has more or less of an acid reaction upon tests; after it has stood in an open vessel for a few hours, this acidity gradually becomes less apparent, and it generally deposits a little mucus, containing traces of acid urate of ammonia. It is extremely prone to other and more complicated changes, and in warm weather, it begins in the course of a few hours to acquire new properties: it becomes alkaline, acquires a highly-disagreeable odour, and lets fall a whitish sediment, consisting chiefly of ammonio-magnesian phosphate, and phosphate of lime; it afterwards smells ammoniacal, and is found to hold carbonate of ammonia in solution. Similar changes may be effected by continued boiling; they are chiefly referable to the decomposition of the characteristic ingredient of the urine, namely *urea*, a substance which is easily resolved into carbonate of ammonia.

The substances always found in healthy urine are the following:

1. Water.
2. Carbonic acid.
3. Phosphoric acid, or superphosphate of lime.
4. Uric acid, or superurate of ammonia.
5. Phosphate of lime.
6. Phosphate of ammonia.
7. Phosphate of soda.
8. Phosphate of magnesia.
9. Common salt.
10. Sulphate of soda.
11. Albumen.
12. Urea.

To which may probably be added,

13. Fluoric acid.
14. Benzoic acid.
15. Acetic or lactic acid.
16. Gelatine.
17. Lactate or acetate of ammonia.
18. Sulphate of potassa.
19. Fluate of lime.
20. Muriate of ammonia.
21. Sulphur.
22. Silica.
23. Mucus.
24. Colouring and odorous matter.

To this extensive list may be added a great variety of occasional or accidental ingredients derived from particular kinds of food or medicine, and which pass off by the kidneys; and lastly, certain substances which are apparently products of disease, such as oxalic acid or oxalate of lime, carbonate of lime, cystic oxide, sugar, and nitric acid.

From this complicated character of the urine, from the variations to which the quantity and quality of its components are liable, and from the facility with which it passes into a state of decomposition, and is modified by heat and other chemical agents, it becomes extremely difficult to give even an average statement of the relative proportions of its usual ingredients; as a specimen, however, of such an attempt, I quote the following from Berzelius:

Water	933.00
Urea	30.10
Sulphate of potassa	3.71
Sulphate of soda	3.16
Phosphate of soda	2.94
Muriate of soda	4.45
Phosphate of ammonia	1.65
Muriate of ammonia	1.50
Free lactic acid (acetic)	17.14
Lactate of ammonia (acetate)	
Animal matter soluble in alcohol	
Urea not separable from the preceding	
Earthy phosphates, with a trace of fluate of lime	1.00
Uric acid	1.00
Mucus of the bladder	0.32
Silica	0.03
	1000

A question has arisen as to the existence of *free* acid in the urine, as stated by Berzelius and others; Dr. Prout regards the acidity of the urine as the result of the presence of acid or super-salts, and especially of superphosphate of lime and superurate of ammonia. Dr. Turner observes, "that a very strong argument, which to him appears conclusive in favour of this view is, that on adding muriatic acid to recent urine, minute crystals of uric acid are gradually deposited, as always happens when this acid subsides slowly from a state of solution; but on the contrary, if no free acid is added, an amorphous sediment, which Dr. Prout regards as superurate of ammonia, is obtained." We know, however, too little of the mutual actions of the complex ingredients of the urine, to sanction this opinion; carbonic acid is certainly, sometimes at least, present in a free state; and whether other acids may or may not exist free, and therefore in variable quantities in reference to the bases, is, I think, a question which cannot, at present, be determined. At all events, the presence of free acid in certain morbid states of the urine, cannot admit of a doubt. One important consequence of the acid state of the urine appears to be the retention of certain difficultly-soluble salts in permanent solution; for whenever the urine is neutralized by an alkali, these are more or less precipitated; an effect of this kind not unfrequently takes place in the body, as we see from the turbid state in which the urine is voided after sufficient doses of the caustic or carbonated alkalis, or of magnesia.

The properties and composition of the ordinary acids, bases, and salts of the urine, are already before the reader; the chemical history of *urea*, and of *uric acid*, bodies which peculiarly characterize urine, remain to be noticed.

Urea is the principle which confers upon urine its chief peculiarities. It may be obtained by slowly evaporating urine to the consistency of syrup; on cooling it concretes into a saline mass, which, by digestion in alcohol, furnishes urea. By carefully distilling off the alcohol, the urea remains in the form of a brown crystallized mass, which, by purification, furnishes colourless prismatic crystals. Or, concentrated nitric acid may be added to the brown urea, which forms with it a crystallized mass, which, after having been washed with a little cold water, is to be dried by pressure in blotting-paper. The *nitrate of urea* thus formed is to be decomposed by neutralizing it with a strong solution of carbonate of potassa, and the solution set aside after having been duly evaporated, to separate the nitre by crystallization. The mother-liquor, which is an impure solution of urea, is mixed with animal charcoal into a paste, which, after some hours, is lixiviated with cold water; the urea is dissolved, and the solution evaporated to dryness, at a low temperature. The residue is then digested in pure alcohol, which deposits crystals of urea on cooling. (Prout, *Med. Chir. Trans.*, viii.)

The form of these crystals is a four-sided prism; they are transparent, colourless, of a peculiar and cooling taste, a faint, but not urinous odour, neutral, slightly deliquescent, and of a specific gravity $=1.35$. Urea dissolves in about its weight of water at 60°, and in 5 parts of cold, and 1 of boiling alcohol. This solution is not prone to decomposition unless other ingredients of the urine be present; it is then, by continued ebullition, almost entirely resolved into carbonate of ammonia. Urea is also decomposed by the caustic alkalis and alkaline earths. It fuses at 250°, and at a somewhat higher temperature it is resolved into carbonate of ammonia and *cyanuric* acid. Although not alkaline, urea forms definite and crystallizable compounds with nitric and oxalic acids; and this property forms a good characteristic test of the presence of urea.

Urea consists of

				Prout.
Carbon	1	6	20.00	19.975
Hydrogen	2	2	6.67	6.650
Oxygen	1	8	26.66	26.650
Nitrogen	1	14	46.67	46.650
Urea	1	30	100.00	99.925

By referring to the composition of cyanic acid, ammonia, and water, it will be apparent that 2 atoms of urea $=2\,(car+{}_2h+o+n)$ are equivalent to, and contain the elements of 1 atom of *hydrated cyanate of ammonia* $=(\mathrm{A}+cy'+q)$ or $(n+{}_3h)+(n+{}_2car+o)+(h+o)$. Hence the production of urea by the mutual action of ammonia, cyanic acid, and water, as by decomposing cyanate of silver by muriate of ammonia, or cyanate of lead by a solution of ammonia; in the latter case, oxide of lead falls, and it might be presumed that cyanate of ammonia would be formed, but on evaporating the filtered liquor, quadrangular crystals are obtained, which yield no ammonia by the action of potassa, nor do they precipitate solutions of lead or of silver, as is the case with the soluble cyanates; in this case, therefore, *urea is formed artificially*, and it presents a curious case of isomerism.

Uric Acid. Lithic Acid. This acid has been mentioned as one of those which are found in human urine; it often constitutes urinary concretions; it is found in the urine of birds of prey and of those which feed on fish and animal matter; it is also, however, abundant in the excrement of the parrot and of other birds which feed upon vegetables only. It occurs in the excrement of large snakes, especially that of the *Boa constrictor*, which consists of white nodules containing little else than urate of ammonia. From this substance, uric acid may be obtained, by powdering it, digesting and dissolving it in solution of caustic potassa, and dropping the solution into dilute sulphuric, muriatic, or acetic acid; the precipitate, when thoroughly edulcorated and dried, is pure *uric acid.* It is a white, tasteless, inodorous powder, nearly insoluble in water, requiring, according to Prout, 10,000 parts of water at 60° for solution; it is insoluble in alcohol and in ether, it reddens litmus, and combines with bases. When mixed with nitric acid, and evaporated carefully to dryness, a crimson or scarlet compound remains, which becomes bright purple when moistened with ammonia; this is a ready and characteristic test of uric acid.

Uric acid is decomposed by chlorine; when *dry*, and heated in the gas, cyanic and muriatic acids are formed; if *moist*, cyanic and carbonic acids, while muriate and carbonate of ammonia remain in solution. When uric acid is distilled *per se* it yields carbonate and hydrocyanate of ammonia, and a sublimate of *pyro-uric* or *cyanuric acid*[*].

Dry uric acid, consists of

				Liebig.	Prout.
Carbon	5	30	35.7	36.11	39.875
Hydrogen	2	2	2.3	2.34	2.225
Oxygen	3	24	28.6	28.19	26.775
Nitrogen	2	28	33.4	33.36	31.125
Uric acid	1	84	100.0	100.00	100.000

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[*] *Cyanuric acid* may also be obtained from *urea*, which, when gradually heated in a retort to about 600° is resolved into ammonia and anhydrous cyanuric acid; the latter remains in the retort; to purify it, it is dissolved in hot sulphuric acid, and nitric acid dropped in till it occasions no further effervescence, and the solution becomes colourless: when cold, water is added, which throws down cyanuric acid in the form of a white crystalline powder. It may be obtained in large crystals, by evaporating its hot saturated solution to about half its bulk, at a temperature of 150°, and allowing it gradually to cool upon the sand-bath. Cyanuric acid is remarkably unchangeable by the action of acids, and when heated it sublimes unchanged in the form of acicular crystals. It may be obtained *anhydrous*, by dissolving the crystals in hot sulphuric acid, from which it is deposited on cooling. According to Wöhler and Liebig, cyanuric acid consists of 3 atoms of cyanogen, 3 hydrogen, and 6 oxygen; so that its ultimate components are

Carbon	6	36	27.8
Nitrogen	3	42	32.6
Hydrogen	3	3	2.4
Oxygen	6	48	37.2
Cyanuric acid	1	129	100.0

The conversion of hydrous cyanic acid, and of urea, into cyanuric acid, and other cases of its formation, will be intelligible by reference to its ultimate components; the hypothetical arrangements of which these will admit are too numerous to be here inserted.

Dr. Prout's latest analysis, above quoted, gives 6 instead of 5 atoms of carbon, and places the equivalent of uric acid at 90 instead of 84. The analyses of the urates, are not, however, sufficiently numerous, to enable us accurately to determine the equivalent of the uric acid, and Liebig has adduced strong evidence in favour of the above atomic constitution. (*Ann. de Chim. et Phys.*, LV. 58.)

Urate of Ammonia. ($A+ur'$.) The neutral urate of ammonia is soluble, according to Prout, in 480 parts of water at 60°, and the solution yields a precipitate of uric acid on the addition of the other acids: triturated with solution of potassa it evolves ammonia: this salt occurs in the urine, and in urinary calculi; but according to Coindet the excrement of snakes and birds contains a *binurate of ammonia.*

Urate of Potassa ($P+ur'$) is formed by digesting uric acid in a warm solution of caustic potassa, till it is neutral; on cooling, the salt is deposited in granular crystals, or by slow evaporation, in crystalline scales soluble in about 500 parts of cold water; but it is more soluble in boiling water, especially if there be excess of alkali; in this case, however, the neutral urate is also deposited. When urate of potassa is dissolved in solution of potassa, carbonic acid throws it down in the form of a bulky gelatinous precipitate; it is also precipitated by carbonate of ammonia. When the dry salt is exposed to air it absorbs carbonic acid, and carbonate and binurate of potassa are formed; digested in a solution of carbonate of potassa, uric acid forms a transparent gelatinous hydrated urate of potassa, and the solution contains bicarbonate of potassa. When subjected to destructive distillation, urate of potassa leaves cyanuret of potassium. When uric acid is fused with caustic potassa, ammonia is evolved, and oxalate of potassa formed.

Urate of Soda. ($S+ur'$.) The mutual action of uric acid and solution of caustic soda, resembles that of potassa. This salt constitutes the white concretions which form in the joints of gouty persons, and which are called *chalk-stones.* (Wollaston.)

Urate of Lime. ($C+ur'$.) The solution of uric acid in lime-water yields pulverulent or minute acicular crystals of this salt. The addition of muriatic acid to the solution, throws down a *binurate of lime.*

Urate of Baryta ($B+ur'$) may be formed by digesting uric acid in baryta-water; or by adding urate of potassa to soluble barytic salts. *Urate of strontia* and *urate of magnesia* may also be obtained by double decomposition: according to Wetzlar, when uric acid is boiled in water with the earthy carbonates, carbonic acid is expelled, and urates of the bases are formed. Many of the metallic urates may be formed by double decomposition: the *urate of mercury* so obtained yields, when heated, carbonic and hydrocyanic acid, and much cyanic acid, but no free cyanogen. (Wöhler.)

Purpuric Acid. This compound was first accurately examined and distinguished as a peculiar acid, by Dr. Prout, (*Phil. Trans.*, 1818.) Its name indicates the colour of its compounds, for, though colourless itself, it produces purple salts. It may be obtained as follows: (Turner's *Elements.*) "Let 200 grains of uric acid prepared from the urine of the *Boa constrictor* be dissolved in 800 grains of pure nitric acid, diluted with an equal weight of water, the uric acid being added gradually, in order that the heat may not be excessive. Effervescence ensues after each addition, nitrous acid fumes appear, heat is evolved, and a colourless solution is formed, which on standing in a cool place for some hours, yields colourless crystals which have the outline of an oblique rhomboidal prism. By gentle evaporation, an additional quantity may be obtained. They contain nitric and purpuric acid, and ammonia; should be dissolved in water, and be exactly neutralized by pure ammonia, and the liquid then digested in a solution of potassa until the ammonia is wholly expelled: on pouring this solution into dilute sulphuric acid, purpuric acid is set free, which being insoluble in water, subsides as a granular powder, of a white colour if pure, but commonly of a yellowish-white tint." Dr. Turner observes "that considerable uncertainty prevails as to the nature of purpuric acid. Vauquelin denied that its salts have a purple-colour, attributing that tint to some impurity; and Lassaigne is inclined to the same opinion; (*Ann. de Chim. et Phys.*, xxii. 334;) but from the intense colour given even by a very minute quantity of purpuric acid, the opinion of Dr. Prout appears to me the more probable. The composition of the acid is likewise unsettled, for Prout has expressed a doubt of the accuracy of the analysis which he formerly published."

Dr. Prout's analysis represented Purpuric acid as $(2\,car + 2\,h + 2\,o + n)$ its equivalent being 44. This acid reddens in the air, either from the formation, or absorption of ammonia: it reddens when heated, and burns away without any peculiar odour. It is decomposed by concentrated nitric acid and by chlorine. It requires more than 10,000 parts of water for solution, and is soluble (without decomposition,) in sulphuric acid. It expels carbonic acid from the carbonated alkalis, and forms red salts, most of which contain 2 atoms of acid to 1 of base.

PURPURATE OF AMMONIA forms four-sided prisms of a red colour and sweetish taste, soluble in 1500 of cold and in much less of hot water, and insoluble in alcohol and ether: the aqueous solution is carmine-red. *Purpurate of potassa* is dark-brownish purple, and much more soluble in water than purpurate of ammonia. *Purpurate of soda* requires 3000 parts of water at 60° for solution. *Purpurate of baryta* is thrown down in the form of a dark-green powder, on mixing acetate of baryta with purpurate of ammonia; its aqueous solution is purple. *Purpurate of lime* is greenish-brown, and yields a purple solution with hot water. *Purpurate of magnesia* is very soluble. Purpuric acid readily dissolves in heated acetic acid, but not in tartaric, citric, or oxalic acid. (Prout.)

Brugnatelli, under the name of *Erythric acid*, (from ερυθραινειν, *to redden*,) has described a substance which Dr. Prout regards as the crystallized compound of nitric and purpuric acid and ammonia, above mentioned. The *rosacic acid* of Proust appears to be a modification of uric acid, perhaps tinged with a little purpurate of ammonia: it forms what is usually termed the *lateritious sediment* which is deposited by urine in the course of some febrile disorders.

COMPOSITION OF URINE IN DISEASES. The urine is liable to infinite modifications both in the quantity and quality of its components, and when these are regular or constant, or when they exceed certain limits, they are regarded as constituting morbid states of the secretion.

I have already adverted to the new characters which the urine sometimes acquires from particular kinds of food or medicine. Odorous principles are often carried off by it, as in the case of asparagus, oil of turpentine, and several other varieties of volatile oil. During a course of mercurial friction, mercury is said to have been found in the sediment, which, in such cases, is generally deposited; and traces of iron have been found during a course of chalybeate remedies. Nitre, ferrocyanuret, and sulpho-cyanuret of potassium, iodine, and iodic salts, several borates, carbonates, chlorates, and even silicates, and many of the acids and alkalis, have also been traced passing off from the stomach by the kidneys; some of the vegetable salts with alkaline bases appear to suffer such decomposition, as to act upon the urine in the manner of free alkalis, the acid being decomposed, probably by the process of digestion. Among the substances which pass off by urine, none are more remarkable, or more easily observed, than colouring-matters of vegetable origin, such as those of many fruits, logwood, madder, rhubarb, and also several astringents; these sometimes are not apparent, till the urine is tested by an alkali, or by solution of iron. The mineral acids, alcohol, ether, camphor, empyreumatic oils, musk, the colouring-matters of cochineal, litmus, and *sap-green* (which is the green extractive of the *Rhamnus catharticus*) and others, insoluble in water, are said not to pass by urine in an unchanged state.

In many diseases, there is an excessive secretion of *acid* along with the urine; this is sometimes *uric acid*, which we shall presently refer to, and sometimes oxalic or even nitric acid, neither of which belong to healthy urine; I have also observed a peculiar acid state of urine depending upon a volatile acid, which I believe to be either the acetic, or lactic. Nor is an alkaline state of urine, or at least a deficiency in the proper proportion of acid, at all uncommon; it is often the result of particular food and medicine, and sometimes habitual; in such cases, the urine has a tendency to a white deposit, or film; and is generally opalescent, when voided, or speedily becomes so. This is generally the case in injuries of the spine affecting the nerves which supply the kidneys, and in these cases ammoniacal urine is sometimes voided.

The relative proportion of urea fluctuates on one side or other of the healthy standard, from a variety of causes: when it is defective, the urine loses its putrefactive tendency, and when long boiled or heated, there is not that production of ammonia which belongs to healthy urine. In inflammatory affections of the liver, in hysteria, in some cases of excessive secretion of albuminous matter, and in some of diabetes, there is this deficiency of urea. In other cases, urea is in excess, so that nitric acid added to the urine causes a deposition of nitrate of urea. Dr. Prout judges of the presence of excess of urea, by putting the urine into a watch-glass, and dropping in a little nitric acid, so as to collect at the bottom; if there be a separation of crystals of nitrate of urea in the course of less than half an hour, that ingredient is probably present in morbid proportion.

Albumen is a common ingredient in healthy urine, but always in very small relative proportion; in some cases of disease, it is so abundant as to coagulate by heat, or even sometimes, spontaneously, within the bladder: it is also recognised by the precipitate which it affords to ferrocyanuret of potassium; but in applying this test, and, indeed generally, in judging of the state of the urine of any individual, it should be previously ascertained that it is not naturally subject, (which is at times the case,) to excess or deficiency of this, or others of its components. In some forms of dropsy, especially where there is renal disease, excess of albumen is often observed; in these instances the urine is scanty, and its specific gravity below the usual average, in consequence of deficiency in saline matter and in urea; and it deserves notice, that in some such cases, urea has apparently existed in the blood.

A peculiar *red* colouring-matter, differing from any uric or purpuric combination, is sometimes present in the urine, associated with the lateritious sediment; it is soluble in alcohol, but has not been accurately examined. Messrs. Brett and Bird have adverted to such cases in a paper published in the *Medical Gazette*, for August, 1834. A *blue* and *black* colouring-matter have been observed in the urine, but they are of very rare occurrence; the former is the *cyanurin* of Braconnot, and the latter the *melanic acid* of Prout? These appear to be peculiar organic compounds; the former has apparently been mistaken for Prussian-blue. The yellow, brown, or green tint, which urine sometimes acquires, in jaundice and obstructions of the liver, seems to depend upon the presence of bile or of its colouring-matter. In these cases, muriatic acid brightens the colour, or renders it green.

The most extraordinary morbid change which urine suffers, is that connected with the formation of sugar in the disease called *diabetes*. This urine does not easily putrefy, and may be made to undergo vinous fermentation; it is usually of a pale colour, and more or less sweet to the taste, and its specific gravity commonly above the healthy standard *;

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* The following table constructed by Dr. Henry, shows the quantity of solid extract, in a wine-pint of urine of different specific gravities, from 1.020, to 1.050. In the experiments which furnished the data of this table, the urine was evaporated by a steam-heat till it ceased to lose weight, and left an extract which became solid on cooling. (*Med. Chir. Trans.*, ii., 118.) This is a useful table to the medical practitioner, who, in cases of diabetes, may draw important inferences respecting the progress of the disease, and the influence of medicines, from the differing density of the urine.

Specific gravity compared with 1000 parts of water at 60°.	Quantity of solid extract in a wine-pint.	Quantity of solid extract in a wine-pint, in				Specific gravity compared with 1000 parts of water at 60°.	Quantity of solid extract in a wine-pint.	Quantity of solid extract in a wine-pint, in			
	grs.	oz.	dr.	scr.	grs.		grs.	oz.	dr.	scr.	grs.
1020	382.4	0	6	1	2	1036	689.6	1	3	1	9
1021	401.6	0	6	2	1	1037	708.8	1	3	2	8
1022	420.8	0	7	0	0	1038	728.0	1	4	0	8
1023	440.0	0	7	1	0	1039	747.2	1	4	1	7
1024	459.2	0	7	1	19	1040	766.4	1	4	2	6
1025	478.4	0	7	2	18	1041	785.6	1	5	0	5
1026	497.6	1	0	0	17	1042	804.8	1	5	1	4
1027	516.8	1	0	1	16	1043	824.0	1	5	2	3
1028	536.0	1	0	2	16	1044	843.2	1	6	0	3
1029	555.2	1	1	0	15	1045	862.4	1	6	1	2
1030	574.4	1	1	1	14	1046	881.6	1	6	2	1
1031	593.6	1	1	2	13	1047	900.8	1	7	0	0
1032	612.8	1	2	0	12	1048	920.0	1	7	1	0
1033	632.0	1	2	1	12	1049	939.2	1	7	1	19
1034	651.2	1	2	2	11	1050	958.4	1	7	2	18
1035	670.4	1	3	0	10						

it is not, as is often supposed, destitute of, and even generally I believe, not deficient in urea.

Diabetic Sugar may be obtained by evaporating such urine to the consistency of syrup, and keeping it in a warm place, when a granular mass is obtained which must be washed with cold alcohol to abstract the colouring-matter; it may then be dissolved in boiling alcohol, and purified by repeated solution and crystallization, or by the help of animal charcoal. It is a granular sugar, resembling grape-sugar (p. 906,) in appearance and composition: it consists, according, to Prout, of 40.00 carbon, 6.67 hydrogen, and 53.33 oxygen, *per cent.*

The following analyses of diabetic urine are by Meisner; the different samples were taken at different periods from the same individual.

	I.	II.	III.
Substances soluble in ether: urea, lactic acid, lactate of lime, extractive	0.34	0.33	0.65
Substances soluble in alcohol: sugar, extractive, salts	7.06	3.46	5.78
Substances soluble in water: extractive, salts	1.37	3.44	0.99
Mucus, with phosphate of lime and traces of oxide of iron	0.34	0.31	0.46
Water	91.19	92.46	92.10

In *diabetes insipidus*, the urine, though not sweet, is excessive in quantity, and deranged as to composition. The formation of urea is suspended, and such urine leaves, on evaporation, a brown residue, of the consistence of syrup, from which nothing crystallizes, and which is slightly acid. Alcohol of .830 dissolves the greater part of this residue, and leaves, on evaporation, a yellow, deliquescent extractive matter, which resembles that which similar alcohol extracts from the inspissated decoctions of muscular flesh. The portion insoluble in alcohol, appears also to partake of the same properties. (Berzelius.)

Calculous Concretions. It frequently happens that certain ingredients in the urine are secreted in excess, or that, from other causes, they are deposited in a solid form, constituting *sand*, *gravel*, and *calculi*.

Sabulous depositions in the urine are of various characters, but, as far as their leading chemical varieties are concerned, they may be conveniently termed *white sand* and *red sand;* the former consisting usually of *phosphate of lime*, or *ammonio-magnesian phosphate*, or of mixtures of the two; whilst in the latter, *uric acid* predominates. These deposits are frequently temporary only, and may be produced by a variety of accidental causes, which influence the secretion of urine; but when they are more or less constant, or arise from very trifling causes, they then require the utmost attention, as being frequent forerunners of calculus. This tendency to the deposition of solid matter is generally first observed in the urine after it is voided, and as it cools; but it afterwards increases to such an extent that it is voided more or less turbid; and, at length, symptoms of gravel or of stone in the kidney or bladder ensue.

Urinary calculi are composed either of materials that exist at all times in the urine, or of substances which only occasionally appear, and which may, therefore, be regarded as products of disease. The following are their component ingredients:

1. Uric or lithic acid.
2. Urate of ammonia.
3. Phosphate of lime.
4. Ammonio-magnesian phosphate.
5. Oxalate of lime.
6. Cystic oxide.
7. Carbonate of lime.
8. Silica.

Of these substances, the first five are of most frequent occurrence, but their relative frequency varies in different countries and districts. Dr. Yelloly, in a paper on the "Tendency to Calculous Diseases" (*Phil. Trans.*, 1829), has given the following view of the different descriptions of calculi contained in the collection belonging to the Norwich hospital: from this table it will be seen that about one-half of the specimens are composed of one description of material only; and that the remainder consist of alternating layers, more or less numerous, of most of the substances of which human urinary calculi are composed.

Calculi consisting principally of one deposit.

Lithic acid	81
Lithate of ammonia	20
Oxalate of lime	20
Phosphate of lime	4
Fusible calculus, or mixed phosphates; that is to say, calculi composed of the triple, or ammoniaco-magnesian phosphate, mixed with phosphate of lime	37

Calculi consisting of two deposits.

Lithic acid and lithate of ammonia	37
,, oxalate of lime	11
,, mixed phosphates	10
,, phosphate of lime	2
Lithate of ammonia and lithic acid	2
,, oxalate of lime	25
,, mixed phosphates	14
,, phosphate of lime	1
Oxalate of lime and lithic acid	10
,, lithate of ammonia	1
,, mixed phosphates	15
,, phosphate of lime	3
Mixed phosphates and phosphate of lime	2

Calculi consisting of three deposits.

Lithic acid, phosphate of lime, and mixed phosphates	2
,, oxalate of lime, and phosphate of lime	1
,, oxalate of lime, and lithate of ammonia	2
,, oxalate of lime, and lithic acid	4
,, lithate of ammonia, and oxalate of lime	2
,, oxalate of lime, and mixed phosphates	1
Lithate of ammonia, oxalate of lime, and mixed phosphates	3
,, oxalate of lime, and lithic acid	8
,, phosphate of lime, and lithate of ammonia	1
,, lithic acid and mixed phosphates	2
Oxalate of lime, lithic acid, and lithate of ammonia	1
,, lithic acid, and oxalate of lime	1
,, lithic acid, and mixed phosphates	2

Calculi consisting of four or more deposits.

Lithate of ammonia, oxalate of lime, lithic acid, and mixed phosphates	1
Oxalate of lime, lithic acid, oxalate of lime, and mixed phosphates	1
Lithate of ammonia, oxalate of lime, phosphate of lime, oxalate of lime, and lithate of ammonia	1
	328

1. *Calculi composed of uric acid*, of which acid the chemical properties have already been described, are of a brown or fawn-colour; and, when cut through, appear of a more or less distinctly laminated texture. Their surface is generally smooth, or nearly so, being sometimes slightly tuberculated. Before the blowpipe, this calculus blackens, and gives out a peculiar ammoniacal odour, leaving a minute portion of white ash: it is soluble in solution of pure potassa, and heated with a little nitric acid, affords the fine pink compound above-mentioned.

2. *Urate of ammonia* forms calculi, the surface of which is sometimes smooth, sometimes tuberculated; they are made up of concentric layers, and the fracture is fine earthy, resembling that of compact limestone; they are generally of a small size, and rather uncommon, though urate of ammonia often occurs mixed with uric acid. It usually decrepitates before the blowpipe, is more soluble than the uric calculus, evolves ammonia when heated with solution of potassa, and is readily soluble in the alkaline carbonates, which pure uric acid is not.

3. *Phosphate of lime calculus* is of a pale-brown or gray-colour, smooth, and made up of regular and easily-separable laminæ. It is soluble in muriatic acid, and precipitated by pure ammonia, and does not fuse before the blowpipe. *Calculi from the prostate gland*, are frequently composed of phosphate of lime.

4. *Ammonio-magnesian*, or *triple calculus*, is generally white, or pale-gray, and the surface often presents minute crystals; its texture is generally compact, and often somewhat hard and translucent; heated by the blowpipe, it exhales ammonia, and leaves phosphate of magnesia. It is more easily soluble than the preceding; and oxalate of ammonia forms no precipitate in its muriatic solution.

It frequently happens that calculi consist of a mixture of the two last-mentioned substances. in which case they fuse before the blowpipe, and are hence termed *fusible calculi.* They are white, or nearly so, and softer than the separate substances, often resembling chalk in appearance. They are easily soluble in muriatic acid, and if oxalate of ammonia be added to their solution, the lime is precipitated in the state of oxalate.

5. *Oxalate of lime* forms calculi, the exterior colour of which is generally dark-brown, or reddish; they are commonly rough or tuberculated upon the surface, and have hence been called *mulberry calculi.* Before the blowpipe, they blacken and swell, leaving a white infusible residue, which is easily recognised as quicklime. Small oxalate of lime calculi are, however, sometimes perfectly smooth upon the surface, and somewhat resemble a hempseed in appearance.

6. *Cystic oxide* is a peculiar animal substance; the calculi composed of it, which are rare, are in appearance most like those of the ammonio-magnesian phosphate. They are soft, and when burned by the blowpipe, exhale a peculiar fœtid odour. They are soluble in nitric, sulphuric, muriatic, phosphoric, and oxalic acids, and also in alkaline solutions. Cystic oxide forms crystallizable compounds with nitric, muriatic, and oxalic acids. With sulphuric acid it forms a viscid, colourless, and uncrystallizable compound. Its component parts, according to Prout, are carbon 29.9, hydrogen 5.1, oxygen 53.1, nitrogen 29.9. A specimen from a dog, analyzed by Lassaigne (*Ann. de Chim. et Phys.*, xxiii., 329),

yielded carbon 36.2, nitrogen 34.0, oxygen 17.0, hydrogen 12.8; it is probable, therefore, that the latter was a different substance.

7. Dr. Prout, and Mr. Smith of Bristol, (*Medico-Chir. Trans.*, xi., 14) have described calculi composed almost entirely of *carbonate of lime;* but this species is exceedingly rare, and among several hundred calculi which I have examined, I never met with it from the human bladder. Carbonate of lime calculi are small, white, and friable. I have seen many beautiful specimens of carbonate of lime calculus from other animals, and especially from the horse. I have also observed very small and perfectly spherical concretions, composed of carbonate of lime and animal matter, voided in a case in which they apparently came from the prostate gland. In the case of this calculus cited by Mr. Smith, several small ones were voided, and three large calculi of similar composition were removed by operation.

8. *Silica*, as an ingredient in urinary sand and in some calculi, is very rare. It would appear from the statement of Mr. Venables (*Quart. Jour. N. S.*, December, 1829), that it most commonly is voided in the form of sand. Several supposed cases of siliceous sand have been traced to imposture. I have, however, seen, in the possession of Dr. Yelloly, an unequivocal specimen of siliciferous calculus; it was taken from a boy by an operation, and consisted chiefly of oxalate of lime, having small cavities in its interior, lined with an apparently chalcedonic crust, which, on examination, proved to be silica.

These are the principal chemical facts belonging to the history of urinary calculi. In Dr. Wollaston's valuable papers upon this subject (*Phil. Trans.*, 1797 and 1810), much additional information will be found. In the same work (1806, 1808, and 1810), I have given some account of their peculiarities, depending upon their situation, and have also discussed the chemical operation of *solvents*, a subject which I have taken up more in detail in the *Quarterly Journal of Science and the Arts*, vol. viii. The late Dr. Marcet published an excellent dissertation on *Calculous Disorders;* and Dr. Prout's "Inquiry into the Nature and Treatment of Gravel, Calculus, &c.," may be considered as the best medico-chemical work upon the subject.

URINE OF OTHER ANIMALS. From comparative analyses of the urine of different animals it appears, that urea is present in the higher orders. The urine of carnivorous animals is at first acid, but becomes speedily alkaline, and is very prone to putrefaction; it generally contains uric acid, but in small quantity; I found it present in the urine of a camel ; and in the urine of graminivorous animals I found phosphoric salts; Chevreul regards these conclusions as erroneous; and in general, different authorities will be found much at variance in regard to these analyses. According to Hieronymi, as quoted by Berzelius, the urine of the *Lion*, *Tiger*, and *Leopard*, is transparent, and of a nauseous odour and bitter taste; its specific gravity varies in the same individual, from 1.059 to 1.076. As soon as voided, it becomes alkaline from the formation of carbonate of ammonia, which may be expelled by heat, and it again becomes sour. During evaporation it deposits white flakes, and when thus concentrated, the greater part of the urea crystallizes. The urine of these animals yielded

Urea, extractive, and free acetic (lactic?) acid	13.220
Uric acid	0.022
Mucus	0.510
Sulphate of potassa	0.122
Muriate of ammonia, and chloride of sodium	0.116
Phosphate of lime and magnesia, with a trace of carbonate of lime	0.176
Phosphate of potassa and of soda	0.802
Phosphate of ammonia	0.102
Acetate (lactate) of potassa	0.330
Water	84.600
	100.000

The urine of the *hyæna* and *panther* contained the same ingredients, the specific gravity of the former being 1.061 and of the latter, 1.045.

The urine of the *rhinoceros* is muddy, yellow, and, when exposed to air, acquires a crystalline film of carbonate of lime; it effervesces and becomes clear on the addition of an acid. Left to itself, it deposits a yellow powder, composed of carbonate of lime and magnesia, traces of oxide of iron, of silica, and of an azotised animal matter; the clear portion, when evaporated, yields a similar precipitate, and on the addition of muriatic acid, deposits *urobenzoic* acid. (Vogel.)

Elephants' urine is turbid from carbonate of lime and magnesia, it contains no *benzoate*, but much urea. (Vogel.)

The urine of the *horse*, contains urea 0.7, urobenzoate of soda* 2.4, carbonate of soda 0.9 chloride of potassium 0.9, carbonate of lime, 0.2 to 1.1. Water 94.0. Chevreul found sulphate of lime.

The urine of the *camel* yielded carbonate of ammonia and volatile oil by distillation; sulphuric, nitric, and muriatic acid, reddened it: on evaporation it deposited carbonate of lime and of magnesia, with animal matter and a trace of silica. Evaporated to the consistency of syrup, and mixed with nitric acid, it deposited abundance of nitrate of urea. It also contained chloride of sodium, urobenzoate of soda, carbonate of soda, sulphate of potassa in large proportion, some sulphate of soda and carbonate of ammonia, and a trace of oxide of iron. No phosphoric salts or uric acid. (Chevreul.)

The urine of the *cow* contains a large relative proportion of urea and of urobenzoic acid, and exposed to air, deposits small crystals of carbonate of lime and carbonate of magnesia.

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* When the urine of horses and cows is mixed with muriatic acid, the urobenzoic acid is thrown down. It has been examined by Liebig, (*Ann. de Chim. et Phys.*, xliii. 188,) who terms it *hippuric acid*, (from, *ἱππος, a horse*, and *οὐϱη, urine.*) It may be purified by boiling with milk of lime, to which a little chloride of lime is added, till it loses its urinous odour; it is then digested with animal charcoal, and on mixing the hot filtered solution with excess of muriatic acid, hippuric acid separates as it cools in white prismatic crystals. Hippuric acid has much analogy to Benzoic acid, and was generally supposed to be that acid modified by urea or by some other animal matter; Liebig however has shown, that it contains nitrogen, and that its salts are distinct from the Benzoates. It appears to consist of

Carbon	20	120	62.8
Hydrogen	9	9	4.7
Oxygen	6	48	25.1
Nitrogen	1	14	7.4
Hippuric acid	1	191	100.0

This acid, when perfumed by sublimation with a little benzoin, is said to be substituted, as an article of commerce, for genuine benzoic acid.

Urinary calculi are not unfrequent in some of the above and other animals. They vary considerably in composition. Carbonate of lime, carbonate of magnesia, phosphate of lime, and ammonio-magnesian phosphate, are common ingredients; they also often contain a considerable proportion of a peculiar animal matter, of a resinous or fatty character. Oxalate of lime has been detected in the calculus of the rat; and in a calculus from a dog, Lassaigne found a substance which he terms *cystin*, or cystic oxide: (p. 1177.)

§ VI. Soft Solids of Animals. Skin. Gelatin. Muscle, &c.

The skin of animals consists of an exterior covering, the *epidermis*, or *cuticle*, under which is a thin stratum of a peculiar substance, called by anatomists *rete mucosum*, which lies immediately upon the *cutis*, *corium*, *dermis*, or *true skin.*

The *epidermis* varies in thickness on different parts of the body; it is little prone to decomposition, insoluble in water, in alcohol, and in dilute acids. Concentrated nitric and sulphuric acid soften and ultimately dissolve it. The caustic fixed alkalis dissolve it, even when considerably diluted, but not the carbonated alkalis. It is stained by several substances, so far indelibly, that the colour remains till the cuticle peels off. It does not combine with tannin. Corns, and similar indurations, resemble the epidermis in their general chemical characters; and horn, hoof, nails, claws, tortoise-shell, hair, wool, feathers, and scales, may be regarded as modifications of it. All these substances partake more or less of the character of coagulated and dry albumen, and Mr. Hatchett's researches have shown, that the analogies between them are in many cases only broken by the presence of foreign substances.

The general colour of the surface of the body resides in the *rete mucosum*, the tint of which is much dependent upon the influence of light: the black skin of the African, the brown of the Asiatic and American, and the pinkish-white of the European, derive their colour from this peculiar secretion deposited between the *cutis* and *cuticle;* the nature of this substance has not been chemically investigated, but it has been ascertained in regard to the *black* of the negro, that it admits of being bleached by chlorine.

The *cutis*, or true skin, is of a fibrous texture, and when boiled in water is to a great extent soluble, leaving the vascular and nervous filaments which pervade it; the solution, when slowly evaporated, leaves a peculiar animal principle termed *gelatin*.

Gelatin is colourless, semi-transparent, and nearly tasteless. It is softened by long-continued immersion in cold water: in hot water it readily dissolves, and forms a solution of a slightly-opalescent appearance, which, if sufficiently concentrated, concretes on cooling into the tremulous mass usually called *jelly*, and which is easily soluble in water; when dried in a gentle heat, it acquires its original appearance, and is as soluble as before. According to Dr. Bostock, one part of *isinglass* dissolved in 100 of water, gelatinizes on cooling; but in 150 of water it does not concrete. (Nicholson's *Jour.*, xi. and xiv.) When *dry*, gelatine undergoes no change, but its *solution* soon becomes mouldy and putrescent. Submitted to the action of heat, it affords the usual products of animal substances.

Gelatin is readily soluble in diluted acids and alkaline solutions, (Hatchett, *Phil. Trans.* 1800.) Its aqueous solution is not affected by solution of corrosive sublimate, and few of the metallic salts occasion any precipitate in it. Chlorine passed through it occasions a white elastic matter to separate, which is not soluble in water, and which in some properties resembles albumen. Gelatin is insoluble in alcohol and ether, but alcohol does not form a precipitate in its aqueous solution. Solution of tannin occasions a white precipitate in solution of gelatin; and hence, vegetable astringents, such as infusion of galls or of oak-bark, are generally employed as tests for its presence. One part of dry gelatin, such for instance as isinglass, may be detected in 5000 of water by a strong infusion of galls: this precipitate when dried at 212°, consists of about 60 gelatin + 40 tannin. But as tannin precipitates albumen, it cannot be relied on as an unequivocal test, unless we previously ascertain the non-existence of albumen by corrosive sublimate. (Bostock, Nicholson's *Journal*, xiv. and xxi.) Mr. E. Davy recommends sulphate of platinum as a very delicate test of gelatin, with which it forms a brown insoluble compound, in solutions too weak to be affected by vegetable astringents. (*Phil. Trans.*, 1820, p. 119.) This is certainly a very delicate test, and is not affected by albumen.

The action of sulphuric acid upon gelatin has been investigated by Braconnot. Twelve parts of powdered *glue*, and 24 of sulphuric acid, were left together for 24 hours; about 60 parts of water were then added, and the whole boiled for 5 hours, adding water at intervals; the solution was then saturated with chalk, filtered, and suffered to evaporate spontaneously. In a month, crystals were deposited, which, being purified by solution and a second crystallization, much resembled sugar of milk, though they differed from that substance in affording a peculiar acid, called by M. Braconnot *Nitro-saccharine acid*, when acted upon by nitric acid. (*Ann. de Chim. et Phys.*, xiii.)

The dilute acids are excellent solvents of gelatin, especially the acetic; these solutions do not gelatinize, but the gelatin is not decomposed, and re-appears with its former properties on evaporating the acid, or abstracting it by an alkali or other base. The caustic alkalis do not materially affect gelatin, but they sometimes render its solutions turbid by decomposing phosphate of lime, which is often contained in it, and which is soluble, to a considerable extent, in solution of gelatin. The equivalent of gelatin has not been accurately determined in consequence of the indefinite character of its combinations, but calculated in reference to the single atom of nitrogen, its composition may be represented as follows:

							Gay Lussac and Thenard
Carbon	7	. .	42	. .	48.28	. .	47.881
Hydrogen . .	7	. .	7	. .	8.04	. .	7.914
Oxygen . . .	3	. .	24	. .	27.59	. .	27.207
Nitrogen . . .	1	. .	14	. .	16.09	. .	16.998
Gelatin	1	. .	87	. .	100.0		100.000

The different kinds of gelatin differ considerably in viscidity. Mr. Hatchett has remarked that the gelatin obtained from skins possesses a degree of viscidity inversely as their softness or flexibility; the most adhesive kinds of gelatin, too, are less easily soluble in water than those which are less tenacious. The principal varieties of gelatin in common use are,

a, *Glue*, which is prepared from the clippings of hides, hoofs, &c., obtained at the tan-yard; these are first washed in lime-water, and afterwards boiled and skimmed; the whole is then strained through baskets, and gently evaporated to a due consistency; afterwards it is cooled in wooden moulds, cut into slices, and dried upon coarse net-work. Good glue is of a semi-transparent and deep-brown colour, and free from clouds and spots. When used it should be broken into pieces, and steeped for about 24 hours in cold water, by which it softens and swells; the soaked pieces may then be melted over a gentle fire, or in a water-bath, and in that state applied to the wood by a stiff brush. Glue will not harden in a freezing-temperature, the adhesion depending on the evaporation of its superfluous water.

b, *Size* is less adhesive than glue, and is obtained from parchment-shavings, fish-skin, and several animal membranes. It is employed by bookbinders, paper-hangers, and painters in distemper, and is sometimes mixed with flour, gum, &c.

c, *Isinglass* is prepared from certain parts of the entrails of several fish; the best is derived from the sturgeon, and is almost exclusively prepared in Russia. It should be free from taste and smell, and entirely soluble in warm water, which is seldom the case, in consequence of the presence of some albuminous parts. When the jelly of isinglass is concentrated by evaporation and carefully dried, it forms a very choice kind of glue. AIKIN'S *Dictionary*, Art. GELATINE.

Berzelius, and some other chemists, regard gelatin as a *product*, and as in no case pre-existing in the textures whence it is obtained; they consider it as *formed by the action of heat on cellular membrane*, and hence all parts of the body in which cellular membrane exists, may yield gelatin by the continuous action of boiling water; the skin, being condensed cellular membrane, is particularly susceptible of this change; when gelatin is obtained by the action of acids, and without the intervention of heat, it is supposed that they also give rise to its formation. It is certain that, by long boiling, some animal substances are apparently converted into gelatin, in which its pre-existence cannot be demonstrated, and it sometimes seems to be more abundantly formed in this way at temperatures somewhat above the boiling-point of water, than at 212°. It is, perhaps, in favour of this opinion, that gelatin is never found (except, perhaps, in the urine) in the natural fluids or secretions of the body; it was once supposed to exist in the blood, but this has been disproved. Berzelius compares this production of gelatin, to that of sugar from gum and starch. L. Gmelin found that a solution of gelatin, sealed hermetically in a glass tube, and exposed, for some weeks, to a boiling temperature, acquired a brown colour, lost its power of gelatinizing, and left a viscid residue on evaporation.

LEATHER is a compound of gelatin and tannin, formed by steeping the skins of animals in the infusions of certain barks, or other *vegetable astringents.* The skins are previously prepared by soaking in lime-water, which renders the cuticle and hair easily separable, and are afterwards softened by allowing them to enter into a degree of putrefaction, or occasionally by the action of acids. In this state they are submitted to the action of infusion of oak-bark, or other astringent vegetable matter, the strength of which is gradually increased until a complete combination has taken place, which is known by the leather being of an uniform brown colour throughout; whereas, in imperfectly tanned leather, a white streak is perceptible in the centre. A portion of extractive matter, and occasionally other substances, enter into the composition of leather. Davy found the increase of weight in the skin to vary with the tanning material; thus 100 parts of calf-skin tanned in concentrated infusion of galls, increased in weight 64 parts; in a concentrated infusion of oak-bark 34 parts; in a weak infusion 17 parts; in concentrated infusion of willow-bark 34 parts, and in a weak infusion 15 parts; and lastly, in a solution of catechu, 19 parts.

Tawed leather is made by impregnating the skin, duly prepared, with a solution of alum and common salt; it is afterwards trodden in a mixture of yolk of eggs and water. The alum and salt re-act on each other so as to produce sulphate of soda and chloride of aluminum; the latter salt combines with the skin. White glove-leather is thus prepared.

Wash-leather is another important manufacture; in this the skin, after having been prepared and softened, is imbued with oil, and afterwards subjected to a weak alkaline solution.

Curried leather is made by besmearing the skin, or leather, while yet moist, with common oil, which, as the humidity evaporates, penetrates into the pores of the skin, giving it a peculiar suppleness, and making it, to a considerable extent, water-proof. As familiar examples of these processes, the thick sole-leather for shoes and boots is *tanned;* the upper-leather is *tanned* and *curried;* the white leather for gloves is *tawed;* and fine Turkey-leather is *tawed*, and afterwards slightly *tanned.* Aikin's *Dictionary*, Art. LEATHER.

MUSCLE. The muscles, or flesh of animals, is a complex texture, in which the muscular *fibre* is conjoined with cellular membrane, nerves and vessels, fat, and various fluids. On digesting muscular flesh in repeated portions of cold water, albumen, saline substances, and colouring and extractive matters are taken up; on heating the solution, the albumen is coagulated, and on evaporating the remainder in a water-bath, a coloured extract remains, from which alcohol abstracts osmazome* and small quantities of saline matter (lactates?) and leaves a portion of extractive and salts insoluble in alcohol. When the part of the muscular fibre which is no longer acted on by cold water, is digested in hot water, its cellular substance is removed in the form of *gelatin*, and fatty matter separates. The insoluble residue is now little else than *fibrin*, and when dried, presents the characters of that substance as it is above described amongst the ingredients of the blood. When any of the lean, muscular parts of animals are carefully dried, they lose greatly in weight by the evaporation of water; the residue, composed chiefly of albumen, fibrin, and cellular substance or gelatin, may be regarded as the real nutritive matters as articles of food, and it is curious that their relative proportions are not very dissimilar in quadrupeds, birds, and fishes, as shown in the following table. The water was determined by evaporation in vacuo, or at a temperature below 212°.

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* Osmazome, (from *οσμη, odour*, and *ζωμός, broth*,) is that product upon which the peculiar odour of broth or soup, and of dressed meat depends; it is of a yellowish-brown colour, soluble at all temperatures in water and in alcohol, and yields a precipitate with infusion of galls, but does not gelatinize.

100 parts of Muscle of	Water.	Albumen or fibrine.	Gelatin.	Total of Nutritive Matter.
Beef	74	20	6	26
Veal	75	19	6	25
Mutton	71	22	7	29
Pork	76	19	5	24
Chicken	73	20	7	27
Cod	79	14	7	21
Haddock	82	13	5	18
Sole	79	15	6	21

It is commonly supposed that the flesh of young animals is much more abundant in gelatin than that of old ones, but the fact appears to be, that it is merely more soluble and more easily extracted by boiling, and in all cases where it is wished to remove from muscle the whole of the jelly, simmering at a temperature from 100° to 120° should be preferred to boiling, because by a temperature of 212°, the albumen is so firmly coagulated as to envelop the gelatin, and protect it from the solvent power of the water.

The action of sulphuric acid on muscle has been described by Braconnot: 30 parts of beef-fibre, acted on by as much sulphuric acid, yielded a portion of fat, and on diluting the acid mixture, and saturating with chalk, filtering, and evaporating, a substance, tasting like osmazome, was obtained, which was often boiled in different portions of alcohol: the alcoholic solutions, on cooling, deposited a peculiar white pulverulent matter, which Braconnot calls *leucine*, and which, acted upon by nitric acid, affords a crystallizable *nitroleucic acid*. (*Ann. de Chim. et Phys.*, xiii., 118. (See Blood.)

Hair, as already stated, consists chiefly of a substance having the properties of coagulated albumen, and analogous in that respect to the cuticle; but hair also yields more or less gelatin when boiled with water, and the soft silky hair, which easily loses its curl, and is very susceptible of changes in the humidity of the atmosphere, yields gelatin more readily than that which is harsh, strong, and elastic. (Hatchett, *Phil Trans.*, 1800.) Vauquelin also discovered in hair two kinds of oil; the one white, and existing in all hair; the other coloured, yellow from red hair, and dark-coloured when obtained from dark hair. Black hair also contains iron and sulphur. He supposes that where hair has become suddenly gray, the effect is produced by the evolution of acid matter, which has destroyed the colour of the oil.

Membranes, ligaments, tendons, and some other similar textures differ from *horn* and from *indurated cuticle*, and also in some respects from *cartilage*, properly so called, by yielding gelatin when boiled.

§ VII. ANIMAL FAT.

In its general characters and composition, the fat and oil of animals resembles that of vegetables; it is of various degrees of consistency, and contains stearin, margarin, and elain, in varying proportions; the action of alkalis upon these substances, and the properties of the acids and compounds thence resulting, are also in all respects similar to those of the vegetable oils, under the history of which much respecting the animal oils has been necessarily anticipated (p. 951.) The different degrees of consistency of these fats are seen in *tallow*, *lard*, and *oil;* when pure, they have, for the most part, little taste or smell; but by keeping, they become rancid and somewhat sour. The products of their combustion and destructive distillation also agree with those of vegetable oils, provided they are free from *cellular*, or as it is here called *adipose membrane*, from which they may be separated by cutting them, if necessary, into small pieces, and boiling them in water; the fat separates and floats upon the surface, where it concretes on cooling; the foreign matters sink, or are dissolved in the water. For our knowledge of the principal characters of these substances, we are indebted, as already stated, to the laborious accuracy of Chevreul. I shall only here advert to such properties of these fats and oils as have not been above detailed, or to such of them as present distinctive peculiarities.

Human Fat is soft, yellowish, inodorous, and varies a little in different parts of the body; that from the region of the kidneys, when fused, begins to concrete at 76°, and is solid at 64°. It is soluble in 40 parts of boiling alcohol of 0.821, and on cooling, the solution deposits *stearin*, which after having been pressed between folds of blotting-paper at 78°, is colourless, fusible at 122°, and may be cooled to 106° before it begins to congeal; its temperature then rises to 120° from the evolution of latent heat. 100 parts of boiling anhydrous alcohol dissolve 21.5 of this stearin, of which the greater part separates, on cooling, in acicular crystals. The *elain* of human fat is a colourless, inodorous oil, which retains its fluidity at 40°; its specific gravity is 0.913 at 60°; it has a sweetish taste. 100 parts of boiling alcohol dissolve 123 of this elain, and the solution becomes turbid when it has cooled to 170°.

Hogs'-lard is soft, white, and fusible between 78° and 86°. Its specific gravity at 60° is = 0.938, and at 120° = 0.891. When subjected to powerful and continued pressure at 42°, between folds of bibulous paper, it yields, according to Braconnot, 0.62 of its weight of a colourless *elain*, the specific gravity of which, according to Chevreul, is 0.915. 100 parts of boiling alcohol dissolve 123 of this elain, and the solution begins to grow turbid at 144°. The residuary *stearin* (0.38) is inodorous, dry, and granular; when fused, it remains liquid till its temperature sinks to 100°; on congealing, it rises to 109°. When hogs'-lard has become yellow and rancid by exposure to air, it reddens litmus, and contains a volatile acid resembling *caproic acid* (p. 1154.)

Ox Fat, after fusion, begins to congeal at 98°, and the temperature then rises to 102°. It is soluble in 40 parts of boiling alcohol of 0.821, and contains about three-fourths its weight of *stearin*, which is hard, white, and of a granular, crystalline texture; it does not fuse below 112°, and then may be cooled to 102°, when on congealing it rises to 112°. It is translucent, and not greasy, and burns like white wax. 100 parts of anhydrous alcohol dissolve 15.48 of this stearin; when saponified, it yields 0.951 of adipose acids. The *elain* of this fat is colourless, and nearly inodorous: its specific gravity 0.913. 100 parts of boiling anhydrous alcohol dissolve 123.4, and it yields by saponification 0.966 of fat-acids.

After the hair and hoofs have been removed from the feet of oxen, they yield, when boiled with water, a peculiar fatty matter, called *neats'-foot-oil:* it is not subject to rancidity, and remains fluid at 32°. After part of its stearin has been abstracted, it is used for various purposes, and among them, for oiling steeple-clocks, which require, in consequence of the cold to which they are exposed, an oil not liable to solidify.

MUTTON FAT, in external characters, resembles that of oxen, but it is whiter, and acquires a peculiar odour by exposure to air. When melted, it sometimes begins to congeal at 98°, and the temperature then rises to 102°, or it congeals at 104°, and then its temperature only rises to 105° or 106°. It is soluble in 44 parts of boiling alcohol of 0.821. Its *stearine* is white and translucent, and very imperfectly crystalline after fusion. 100 parts of boiling anhydrous alcohol dissolve 16.09 parts. Its *elain* is colourless; specific gravity = 0.913. 100 parts of anhydrous alcohol, at 168°, dissolve 80 parts*.

These two fats are highly important from their application to the manufacture of *soap* and of *candles:* and of late the *stearine* has been employed for the latter purpose, which, fused with from one-fourth to one-eighth part of wax, yields a compound very little inferior to wax, of which the best and genuine *composition candles* are made. Under this term a variety of very inferior articles are sold at comparatively low prices, which have tended to bring this important manufacture into some degree of discredit; and the art of preparing stearin by cheap, and at the same time effective processes, is not as yet very perfect; but this application of it is daily improving, and promises to place the art of making candles not low upon the list of those which have been enlightened and improved by the labours of the chemist.

GOATS' FAT is characterized by its peculiar capreous odour, arising from its containing a peculiar fat, which Chevreul has termed *hircin*, and which, on the separation of its tallow into stearin and elain, accompanies the latter, and cannot be perfectly separated from it. During the saponification of its elain, a liquid fat-acid of a strong goaty odour is formed: it may be obtained by saponifying 4 parts of goat'-fat with 1 of hydrate of potassa and 4 of water, diluting the soap with more water, and decomposing it by phosphoric or tartaric acid, washing the evolved fat-acids, and distilling the sour water and washings; if a drop of the distilled product, evaporated upon a platinum-leaf, leaves any residue, it must be redistilled; the product is then to be saturated by hydrated baryta, evaporated to dryness, and decomposed by distillation with equal parts of sulphuric acid and water: the *hircic acid* then passes over in the form of a colourless volatile oil.

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* When mutton or beef suet is distilled, and the product washed with hot water, it dissolves a peculiar acid, which is Thenard's *sebacic* or *sebic* acid. The solution is precipitated by acetate of lead, and the resulting *sebate of lead* decomposed by its equivalent of sulphuric acid; the sebic acid is then purified by crystallization; it forms colourless, fusible, and volatile acicular crystals; more soluble in hot than in cold water, and very soluble in alcohol. The *sebates of ammonia, potassa*, and *soda*, are soluble; those of *lead, mercury*, and *silver*, are insoluble.

Hircic acid has a capreous and acetic odour, reddens litmus, and dissolves difficultly in water, and easily in alcohol. It forms distinct salts with the bases: *hircate of ammonia* is peculiarly odorous; *hircate of potassa* is deliquescent; *hircate of baryta* is difficultly soluble.

Train Oil. Whale Oil. Common *whale oil* has a specific gravity = 0.927 at 68°; at 32° it deposits *stearin*, and the remaining *oil* is then soluble in 0.82 of its weight of absolute alcohol at 168°. It is easily saponified, yielding a brown soluble soap, which, decomposed by tartaric acid, affords fat-acids, and glycerin, together with traces of *phocenic acid*. The *stearin* of train-oil congeals, after fusion, at between 70° and 80°. It dissolves in 1.8 parts of boiling anhydrous alcohol, from which it crystallizes on cooling, leaving a brown mother-liquor.

Spermaceti Oil. The oil of the spermaceti-whale is more pure, and burns more perfectly and more brilliantly in lamps than common whale-oil; it deposits, as it cools after the death of the animal, a crystalline fatty substance, called *spermaceti*, which is purified by pressure, and boiling in weak solution of potassa; it is then washed, fused in boiling water, and cast into blocks or cakes, which exhibit a beautiful lamellarly-crystalline texture, especially when the interior liquid part is suffered to run out of the exterior concrete case. It has a greasy feel. Its specific gravity is about 0.94: it fuses at 112°. 100 parts of boiling alcohol of 0.821 dissolve 3.5 parts, of which 0.9 fall on cooling. Its solution in hot ether congeals on cooling. It dissolves in the hot oils. When common spermaceti is triturated with alcohol, a little oily matter is abstracted; and when the whole is removed, the residuary pure spermaceti has been termed by Chevreul *cetin*.

Cetin fuses at 120°. 100 parts of boiling absolute alcohol dissolve 15.8 of cetin, but alcohol, of .831, only 3 parts; the greater part separates on cooling in pearly scales. Acids act upon it as on other fats. It is difficultly saponifiable by the hydrated alkalis. Digested for several days between 120° and 190°, with a solution of caustic potassa in twice its weight of water, it is at length converted into a peculiar soap, containing margarate and oleate of potassa, together with an unsaponified fat, which Chevreul terms *ethal*. On decomposing this soap by an acid, ethal, and oleic and margaric acids separate, amounting together to 101.6 parts from 100 of cetin; of this 60.96 parts consist of fat-acids, and 40.64 of ethal: no glycerine is produced, but 0.9 of a yellowish extractive matter; nor is any volatile acid formed.

Chevreul, Saussure, and Berard have analyzed cetin and ordinary spermaceti, and Dr. Ure spermaceti oil, with the following results:—

	Cetin. Chevreul.	*Spermaceti.* Berard.	*Spermaceti.* De Saussure.	*Spermaceti Oil.* Ure.
Carbon . .	81.660	79.5	75.474	78.00
Hydrogen .	12.862	11.6	12.795	11.80
Oxygen . .	5.478	8.9	11.377	10.20

Ethal is obtained by saturating the fat-acids resulting from the decomposition of spermaceti-soap with hydrated baryta, washing away all excess of baryta, drying the residue, and digesting it in cold alcohol or ether, which dissolves the ethal and leaves barytic-soap. The ethal remains, on distilling off the alcohol, in the form of a solid transparent crystalline fat, tasteless and inodorous, and concreting, when fused alone, at 118°; but if fused with water, at 124°. It is volatile when distilled either alone or with water, and in this way it may be purified; it burns like wax. It dissolves in all proportions in alcohol of 0.812 at 128°, and separates, on cooling, in lamellar crystals. It is decomposed when heated with sulphuric and nitric acid. It does not combine with caustic potassa, when pure, but when mixed with soap, it forms a milky fluid, which leaves, upon a filter, a mixture of ethal, with margarate and oleate of potassa, exactly resembling hydrated alumina. According to Chevreul's analysis, ethal consists of

				Chevreul.				
Carbon	16	96	79.4	79.7660	=	Etherine	4	112
Hydrogen	17	17	14.0	13.9452		Water	1	9
Oxygen	1	8	6.6	6.2888				
Ethal	1	121	100.0	100.0000		Ethal	1	121

Porpoise Oil. The oil of the *Delphinus phocœna*, and *Delphinus globiceps*, has been examined by Chevreul. When saponified it yields a peculiar fat-acid, which has been termed *phocenic*, or *delphinic acid.* This acid is best obtained from that portion of porpoise-oil, which remains dissolved in cold alcohol of 0.825. It is saponified, and a *phocenate of baryta* formed, 100 parts of which are decomposed by 205 of phosphoric acid, of 1.12 sp. gr., or by 23.4 parts of sulphuric acid, diluted with twice its weight of water, when nearly the whole of the phocenic acid separates. This acid exists in spermaceti, and in the berries of the *Viburnum opulus.*

Phocenic Acid resembles a volatile oil, retaining its fluidity at 15°; although its boiling-point is above 212°, it volatilizes in the air; it has a rank and acetic odour and acrid taste. Its specific gravity is .932; water at 88° only dissolves an eighteenth part of its weight; alcohol of 0.795 takes it up in all proportions. Anhydrous phocenic acid consists, according to Chevreul's analysis, of

Carbon	20	120	65.6
Hydrogen	15	15	8.1
Oxygen	6	48	26.3
Anhydrous phocenic acid	1	183	100.0

It appears, however, that in the neutral *phocenates*, the oxygen in the acid is to that in the base as 3 to 1, so that the above equivalent is doubled in reference to that of the bases. When the phocenates are heated, they exhale an aromatic odour, and yield, on distillation, an oily liquid, insoluble in potassa. The *phocenates of potassa, soda*, and *strontia* are deliquescent; *phocenate of baryta* yields efflorescent crystals, soluble in twice their weight of water. *Phocenate of lead* is soluble, but during the evaporation of its solution passes into a difficultly-soluble subsalt.

Phocenine is the term applied by Chevreul to that part of the oil which yields phocenic acid, and which is separated, by boiling alcohol, from the common fats.

Fat of Birds. *Goose-fat* is colourless, and of a peculiar taste and odour; when fused, it congeals at 80° to a buttery consistence; subjected to pressure at 30°, it yields 0.68 *elain*, and 0.32 *stearin*, fusible at 112°. *Ducks' fat* fuses at 76°, and yields 72 *elain* and 28 *stearin*, fusible at 120°. *Turkeys' fat* yields 74 *elain* and 26 *stearin*, fusible at 112°.

Fat of Insects. Many insects contain more or less fat, but its peculiarities have been but little examined. The fatty-matter of *cochineal* (*Coccus cacti*) has been examined by Pelletier and Caventou. (*Ann. de Chim. et Phys.*, viii., 271.) It is obtained by digesting cochineal in ether, evaporating, and dissolving the residue in hot anhydrous alcohol, which on cooling deposits the fat; this solution must be repeated till it is colourless. The fat of the *Coccus polonicus*, crystallizes like spermaceti. *Cantharides* also contain a fatty-matter, and an acrid principle, or *cantharadin*. If the watery extract of these insects be digested in alcohol, a tincture is obtained, which by slow evaporation yields a resinous residue; if this be digested in ether, it forms a yellow solution; by spontaneous evaporation it deposits crystalline plates, which may be freed from some adhering colour by alcohol; they resemble spermaceti in appearance, and are soluble in boiling alcohol, but precipitate as it cools. They are insoluble in water. Besides this peculiar principle, cantharides contain a green inert oil, soluble in alcohol; a black matter, insoluble in alcohol, but soluble in water; a yellow substance, soluble in both; a considerable portion of uric acid; a little acetic acid, and phosphates of lime and magnesia.

Eggs*. The yolk of the hen's egg contains about 30 *per cent.* of oil. When the yolk is digested in alcohol a yellow solution is obtained, which deposits a crystalline fat, and leaves, on evaporation, a yellow viscid oil, which easily becomes rancid. The insoluble residue is white and pulverulent, and consists chiefly of albumen, but contains a considerable portion of phosphorus in some peculiar state of combination.

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[*] The changes which the egg undergoes during incubation, have been investigated by Dr. Prout. (*Phil. Trans.* 1822.) New-laid eggs are somewhat heavier than water, but gradually become lighter by the evaporation of water and substitution of air, through the shell. When an ordinary-sized egg is boiled in water it loses about three-tenths of a grain, consisting of the sulphates, phosphates, and carbonates of lime and magnesia, animal matter, and free alkali. Of an egg which weighs 1000 grains, 106.9 parts constitute the *shell*, 604.2 the *white*, and 288.9 the *yolk*. The shell contains about 2 *per cent.* of animal matter, 1 of phosphate of lime and magnesia, and the residue is carbonate of lime with a trace of carbonate of magnesia. The phosphorus contained in the yolk yields the phosphoric acid requisite for the bones of the chick, but the source of the lime for that purpose is not obvious; Dr. Prout could not detect it in the soft parts of the egg, and there is no apparent vascular connexion between the chick and the shell.

The eggs or roe of fish contain also a considerable proportion of oil. The roe of the sturgeon, which, when salted, is known under the name of *caviar*, contains 6.2 albumen; 4.3 fat; 24.3 coagulated albumen and membrane; 6.7 common salt; 0.5 phosphate of lime and oxide of iron; 0.58 water. (John.) The *melt*, or soft roe of the male fish, resembles in composition the liver or the brain; it yields an emulsion with water, containing fat and albumen, and, when incinerated, much phosphoric acid is found in the coal. The liver of many fish is abundant in a peculiar kind of oil; that of the *cod-fish* yields it in considerable quantity.

Ambergris, which is a concretion from the intestines of the spermaceti whale, also contains a considerable portion of fatty-matter, amounting, in some specimens, to 60 *per cent.*, which, according to Chevreul, resembles cholesterine. Pelletier and Caventou have given it the name of *Ambreine*, and it is stated to be convertible by nitric acid, into a peculiar body, which they have called *ambreic acid.* It is only found in the unhealthy animal. (Home's *Lectures on Comparative Anatomy*, vol. i., p. 470.) Benzoic acid has been found in some specimens of ambergris; in others, equally genuine, there are no traces of it.

Musk, *castor*, and *civet*, exclusive of their peculiar and odorous principles, contain distinct species of fat.

Intestinal Concretions sometimes bear a close resemblance to gall-stones (p. 1162), but they often contain peculiar substances, or are formed upon extraneous nuclei. Dr. Ure has described one resembling ambergris. (*Dic.*, Art. Intestinal Concretions.) The oriental *Bezoar stones* are also apparently of this description. Intestinal concretions are not uncommonly formed upon fruit-stones, and seem to be peculiarly frequent where the diet has consisted of oatmeal. One examined by Mr. Children (*Phil. Trans.*, 1822) consisted of animal matter, chiefly gelatine, 25.20; resin 3.90; ammonio-magnesian phosphate 5.16; phosphate of lime 45.34; vegetable fibre 20.30.

Alvine calculi have sometimes a peculiar softness upon the surface resembling velvet. One of these was found by Dr. Wollaston to consist of extremely minute vegetable fibres, or short needles, pointed at both ends, which he immediately conjectured to arise from some kind of food. For some time, however, he failed in his attempts to trace this substance to its origin: but Mr. Clift, of the College of Surgeons, to whom the subject was mentioned in conversation, having put the question, whether this fibrous substance might not proceed from oats, Dr. Wollaston was induced to examine the structure of this seed; and the result fully verified Mr. Clift's conjecture. In Dr. Alexander Monro's *Morbid Anatomy of the Gullet*, mention is made of forty-two alvine concretions collected by the author's father, which were examined by Dr. Thomson. Their structure (with one exception, similar in all) is described by Dr. Monro "as more or less porous, and somewhat like to dried sponge, and when examined by the aid of a magnifying-glass, seems to be made up of a number of very small fibres intimately interwoven with each other, like those in a hat, or in chamois leather; and the interstices between the fibres are filled up with earthy matter." And he adds, "in the centre of the concretion, a *prune* or a *cherry-stone*, or a small piece of bone, or a biliary calculus, is generally found."

Brain. The substance of the brain, nerves, and spinal-marrow, contains fat, together with albumen and phosphorus. When boiled in alcohol it furnishes a peculiar fatty matter, which the solution deposits as it cools, in brilliant scales. It requires a higher temperature than that of boiling water for its fusion, and appears, in many respects, analogous to cholesterine. The same substance is often seen in the alcohol employed to preserve anatomical preparations of the brain and nerves.

According to Vauquelin, the *cerebral substance* consists of water 80.00, white fatty-matter 4.53, red fatty-matter 0.70, albumen 7.00, osmazome 1.12, phosphorus 1.50, acids, salts, and sulphur 5.15. According to Couerbe, the crystalline fatty-matter of the brain is partly *cholesterine.* (p. 1162.) He considers the proportion of phosphorus in the brain of persons of sound intellect, to amount to from 2 to 2.5 *per cent.*, but he asserts that this element is in deficiency in the brain of idiots, and in excess in that of maniacs; amounting in the former to not more than 1 to 1.5 *per cent.*, but in the latter to as much as 3, 4, and even 4.5 *per cent.* If this statement be verified by extended inquiries, it appears to include a most important physiological fact.

Cerumen, or the waxy secretion which lines the external tube of the ear, has been examined by Vauquelin, and more in detail by Berzelius. (*Thier-Chemie: Lehrbuch*, iv.) According to Vauquelin, it contains 0.625 of a brown, buttery oil, soluble in alcohol, 0.375 of an albuminoid substance, and a bitter extractive matter. According to Berzelius, it is a compound of a soft fat, with albumen and another peculiar principle, a yellow bitter extract soluble in alcohol, an extract soluble in water, with alkaline and calcareous lactates; but it contains no chloride, and no soluble phosphate.

§ VIII. SHELL AND BONE.

We are indebted to Mr. Hatchett for two excellent dissertations on the chemical properties of these parts of animals, published in the *Philosophical Transactions* for 1799 and 1800. He has divided *shells* into two classes; the texture of the first is compact, brittle, and resembling porcelain; their surface is smooth, and they are often beautifully variegated. When exposed to a red-heat they crackle, and lose the colour of their enamelled surface, emitting scarcely any smoke or smell. They dissolve in dilute muriatic acid with copious effervescence, and form a transparent solution, in which neither pure ammonia nor acetate of lead produce any precipitate, but carbonate of ammonia throws down carbonate of lime. Hence these, which are called *porcellaneous shells*, may be considered as composed of carbonate of lime, united to a very small portion of gelatine: most of the univalve shells, such as whelks, limpets, cowries, and many of the beautiful convoluted shells of tropical countries, belong to this class.

The second class, or *mother-of-pearl shells*, are tougher, glossy, and iridescent; they are mostly bivalves, and all the oyster and muscle species belong to it. When heated, they exhale smoke and the smell of burned horn; immersed in muriatic acid, they only partially dissolve, and leave a series of cartilaginous layers, and an outer epidermis. Each membrane appears to have a corresponding stratum of carbonate of lime, the solution indicating no trace of any phosphate. The animal part is in some cases, as in mother-of-pearl, tough and indurated, and, when dried, becomes exactly like horn; in other instances, as in the bone of the cuttle-fish, it appears in the form of delicate and tender membrane.

In both classes of shells, therefore, the hardening principle is carbonate of lime; in porcellaneous shells there is very little animal matter, which is gelatine; and in mother-of-pearl shells, it is albumen, and in larger quantities.

Pearls are exactly similar in composition to what is termed *mother-of-pearl*, in which Mr. Hatchett found carbonate of lime 66, albumen 24.

Corals or Zoophytes, according to Mr. Hatchett's researches, may be divided into four classes: 1. The first class resembles porcellaneous shells; they consist entirely of carbonate of lime, with a very minute quantity of gelatinous matter; of this the common white coral (*Madrepora virginea*) is an example. 2. The second consists of carbonate of lime, and a cartilaginous substance, and is therefore analogous to mother-of-pearl shell; to this class belong the *Madrepora ramea*, and *Madrepora fascicularis*. 3. The third class is composed of a cartilaginous matter, with carbonate and phosphate of lime; to this belongs the red coral. (*Gorgonia nobilis.*) 4. The fourth class contains sponges, composed almost entirely of animal matter. (*Phil. Trans.*, 1800.)

Bone and Ivory, like the preceding substances, are essentially composed of soft and hard parts. When ground bone is digested in warm water, a portion of fat is first separated, and by long-continued ebullition, a solution which gelatinizes on cooling is obtained. If fresh bone be immersed in diluted muriatic acid, the fat, gelatine, and bony matter are dissolved, and a kind of skeleton of the bone remains in the form of a cartilaginous substance, which, when dried, exactly resembles horn. It appears, therefore, that the soft parts of bone are, *fat*, *gelatine*, and *albumen*.

The earthy salts, which constitute the hardening principle of bone, are phosphate and carbonate of lime, with a minute quantity of sulphate of lime, and traces of phosphate of magnesia. Fourcroy and Vauquelin obtained from *ox-bones*, animal matter 51.0, phosphate of lime 37.7, carbonate of lime 10.0, phosphate of magnesia 1.3. According to Berzelius, 100 parts of dry *human-bones* contain 33.3 animal matters, 51.04 phosphate of lime, 11.30 carbonate of lime, 2 fluate of lime, 1.16 phosphate of magnesia, soda, chloride of sodium, and water 1.2. Traces of alumina, silica, manganese, and iron, were discovered in bones by Fourcroy and Vauquelin, and of sulphate of lime by Mr. Hatchett.

The *enamel of teeth* is perfectly destitute of cartilage, and consists chiefly of phosphate of lime and a portion of gelatine. Mr. Pepys found its component parts, phosphate of lime 78, carbonate of lime 6, gelatine 16.

The same chemist has given the following as the composition of the teeth (Fox, *On the Teeth.*)

	Roots of the Teeth.	Teeth of Adults.	First Teeth of Children.
Phosphate of lime	58	64	62
Carbonate of lime	4	6	6
Cartilage	28	20	20
Water and loss	10	10	12
	100	100	100

The difference between the structure and composition of the enamel and bone of teeth, is well illustrated in the teeth of some of those graminivorous animals, in which the enamel, instead of being external, alternates in layers with the bone: the section, for instance, of the elephant's tooth exhibits three distinct substances, namely, a hard and a softer bone, and an enamel; when steeped in dilute muriatic acid, the latter is entirely dissolved; the bony portions leave variable proportions of cartilage.

We have as yet but few accurate comparative analyses of the bones of different animals. In human bone carbonate of lime is much more abundant, according to Berzelius, than in that of the ox: the relative proportions of these salts also vary considerably in other cases, as is shown in the following analyses of the earthy residue of different bones, by De Barros. (Berzelius's *Lehrbuch.*)

	Phosphate of Lime.	Carbonate of Lime.
Lion	95.0	2.5
Sheep	80.0	19.3
Hen	88.9	10.4
Frog	95.2	2.4
Fish	91.9	5.3

The bones of fish appear, in almost all cases, to contain much less earthy matter than those of quadrupeds or birds. According to Chevreul, the bones of the head of the cod contain, animal matter and moisture 43.94, phosphate of lime 47.96, carbonate of lime 5.50, phosphate of magnesia 2.00, soda-salts, chiefly chloride, 0.60. The bones of the *haddock* contain, according to Dumenil, animal matter 37.63, phosphate of lime 55.26, carbonate of lime 6.16, traces of soda, salts, and loss, 1.22.

The cartilaginous part of the bone is that which is first formed, as seen in the skeletons of young animals; and in the case of a bone being broken, the animal portion is first secreted, and it is gradually hardened by the deposition of the earthy salts, so as perfectly to reunite the fractured extremities; it is stated by Lassaigne, that in the newly-formed bone, phosphate of lime at first predominates; but that when the new portion is perfected, it contains the same relative proportions of phosphate and carbonate, as those of the original bone.

The bones, including their animal matter, are the most durable portion of the animal fabric, hence the proposal of storing them up as occasional sources of nutriment; for not only is the cartilaginous portion unimpaired in bones which have been kept dry for many years, but it has even been found perfect in bones of apparently antediluvian origin. The best mode of extracting the nutritious part of the bone for human food consists in grinding it fine, and subjecting it with water to a heat of about 212°, in a digester; or the earthy part may be removed by muriatic acid. When dogs, and some other animals are fed on bones, the nutritive portion is effectually abstracted by the gastric juice, and the excrement, in such cases, is almost entirely phosphate and carbonate of lime, forming the *Album Græcum* of old pharmacy.

When bones are submitted to destructive distillation, the gelatine and albumen which they contain is abundantly productive of ammonia; water and carbonic acid are also formed, and a portion of fœtid empyreumatic oil. (p. 1131.) There remains in the vessel a quantity of charcoal mixed with the earthy substances, which is, in that state, called *ivory black.* It is employed as the basis of some black paints and varnishes, and is applicable to many other useful purposes in the arts, as a variety of animal charcoal.

§ IX. ANIMAL FUNCTIONS.

Chemistry has hitherto done little towards elucidating the *functions of animals*, and it is scarcely possible to describe the little that has been done, without such frequent reference to anatomical and physiological inquiries as would be irrelevant to the present work: I shall, therefore, only enumerate the principal chemical phenomena that have been experimentally illustrated, in relation to this subject.

Digestion is a process by which the food of animals is converted, by a series of successive changes, into *chyle*, and which, in conjunction with *respiration*, tends to the production of blood. The mechanism by which this important function is carried on differs considerably in the different classes of animals: the present remarks will relate chiefly to man, and to the carnivorous tribe.

The food of all living beings is necessarily of organic origin, some deriving it from animal, some from vegetable sources, and some from both. But all organic substances are not susceptible of digestion, and this is especially the case with those belonging to the vegetable kingdom; and as one of the functions of the stomach and intestines consists in separating the nutritive and digestible from the indigestible substances, those organs are generally more complicated and extended in graminivorous than in carnivorous animals. The most nutritive and digestible principles of vegetables, are those which include nitrogen as one of their elements, such as albumen, gluten, and perhaps a few varieties of extractive matter; they bear some resemblance, in this respect, to animal products. Yet it is also to this class that the most virulent poisons belong; so that the existence or non-existence of nitrogen is far from a criterion of their fitness or inaptitude for food. Starch, gum, and sugar, are also generally regarded as highly nutritive principles, and they are so in conjunction with the former, or with animal food; but these and other substances destitute of nitrogen, are not alone capable of indefinitely supporting the life of gramino-carnivorous tribes; and it is doubtful how far graminivorous animals can continue to exist upon them. The experiments of Majendie, and of Tiedemann and Gmelin, upon these subjects, should be consulted; they seem to show the curious fact that no *single* substance is adapted to animal sustenance, for geese fed upon gum died on the sixteenth day, those fed upon starch on the twenty-fourth day, and those fed on boiled white of egg on the forty-sixth day: in all these cases they dwindled away, and died as if of starvation.

Woody fibre is generally regarded as indigestible, and many of its modifications, in their ordinary states, certainly are so, for they pass through the stomach and bowels unchanged; but when minutely divided, or modified by heat, or in the attenuated state in which lignin exists in certain roots and fruits, it probably is more or less digestible. Resins, and analogous substances insoluble in water, are also unfit for food. Vegetable acids, alcohol, certain aromatics, and oils, are rather to be considered as condiments and stimulants, and so far essential to digestion, than as contributing to the direct nutritive power of food. Among animal substances, hair, feathers, the shells of insects*, and a few other products, belong to the class of absolute indigestibles.

The food, duly masticated in the mouth, and blended with a considerable portion of saliva, is propelled into the stomach, where it soon undergoes a remarkable change, and, in the course of a few hours, is converted into an apparently homogeneous pulpy mass, which has been termed *chyme*, and which has little or no resemblance to the original food. This very curious change is only referable to the operation of the *gastric juice* (p. 1164); the remarkable property of living substances to resist its action is curiously illustrated by the circumstance that the stomach itself, after death, is occasionally eaten into holes by it; it coagulates albuminous substances, and afterwards softens and dissolves the coagulum.

Although animals drink copiously with their food, the consistency of the chyme is not apparently much affected by it, and by the time that it reaches the right, or pyloric extremity of the stomach, the greater part of the liquid has disappeared. Sir Everard Home has shown that the liquids are removed by absorbents belonging principally to the left, or cardiac portion of the stomach, and that during digestion there is an imperfect division of the stomach into two cavities, by the contraction of the bands of muscular fibres about its centre. He has also shown that these liquids reach the kidneys, and pass off by urine; and was led to believe that the spleen was the channel of communication; an opinion, however, which his subsequent researches tended to disprove.—(*Lectures on Comparative Anatomy*, p. 221.)

The chyme passes from the stomach into the small intestines, where it soon changes considerably in appearance; it becomes blended with bile, and is separated into two portions, one of which is white as milk, and is termed *chyle;* the other passes on to the large intestines, and is ultimately voided as excrementitious †. The chyle is absorbed by the *lacteals*, which terminate in the common trunk, called the *thoracic duct;* it is there mixed with variable proportions of lymph, and poured into the venous system. The *excrements of animals* have been examined by Berzelius (Gehlen's *Journal*, vi.;) by Vauquelin (*Ann. de Chim.*, xxix.;) and by Thaer and Einhoff.

Chyle has been examined by several chemists, and their results are not widely different. During some physiological researches in which I assisted Sir B. Brodie, I had an opportunity of collecting it in considerable quantities in several carnivorous and graminivorous animals, and presented an account of my experiments upon it to the Royal Society, (*Phil. Trans.*, 1812.) Chyle is an opaque white fluid, having a sweetish saline taste; its specific gravity is inferior to that of the blood. It exhibits slight traces of alkaline matter when tested by infusion of violets; soon after removal from the thoracic duct, it gelatinizes spontaneously, and afterwards gradually separates into a firm yellowish-white coagulum, and a transparent colourless serum; so that, like the blood, it enjoys the property of spontaneous coagulation.

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* Odier has applied the term *Chitin*, (from *χιτων, a coat of mail,*) to the hard shells, and elytra of insects, or to the most insoluble parts: they would appear, however, from Mr. Hatchett's experiments, to be modifications of indurated albumen, analogous to scales, feathers, nail, horn, &c.

† The necessity of bile to the formation of chyle has been illustrated by Sir B. Brodie (*Quarterly Journal, O.S.*, xiv., 341). When the choledoch duct was tied so as effectually to prevent the flow of bile into the intestine, no chyle was formed; the chyme appeared little altered; and the lacteals, instead of their usual milky fluid, contained a transparent fluid, consisting, apparently, of lymph, and of the more fluid part of the chyme. Tiedemann and Gmelin assert, that under these circumstances chyle is formed; and Berzelius also says that chyle is formed, but that it is transparent, because its oil is not saponified: but it must surely be difficult in these cases to distinguish between *transparent chyle* and certain modifications of lymph.

The *coagulum of chyle* possesses properties closely resembling those of the caseous portion of milk, and may hence be considered as a variety of albumen; the *serum of the chyle*, when heated, deposits a few flakes of albumen, and by evaporation to dryness affords a small proportion of a substance analogous to sugar of milk. Small portions of phosphate of lime, carbonate of soda, and common salt, may also be detected in the chyle. In these experiments I found no essential difference in the chyle of graminivorous and carnivorous animals; I examined it from the horse, the ass, the dog, and the cat; Dr. Marcet thinks that the former is less abundant in albumen than the latter. (THOMSON's *Annals*, vol. vii.) From a comparative analysis of the chyle of two dogs, by Dr. Prout, of which one was fed on vegetable, and the other on animal food, the components were found to be as follow (*Ann of Phil.*, xiii. 25):—

	Vegetable Food.	Animal Food.
Water	93.6	89.2
Fibrine	0.6	0.8
Incipient albumen ?	4.6	4.7
Albumen with a little red colouring-matter	0.4	4.6
Sugar of milk	a trace	0.0
Oily matter	a trace	a trace
Saline matter	0.8	0.7
	100.	100.

There can be little doubt that the bile performs an important part in the change which the chyme suffers in the small intestines; it has been conjectured that its aqueous, and perhaps its alkaline, parts, are employed as components of chyle, while the albumino-resinous matter combines with the excrementitious portion, and tends to stimulate the intestinal canal towards promoting its propulsion. Whether the bile is absolutely necessary to the formation of chyle, is a question that has not been satisfactorily answered; but its importance is demonstrated by the emaciation that attends its deficiency, and by the disordered state of bowels that accompanies its imperfect secretion. Sir Everard Home, in his *Lecture on the Functions of the Lower Intestines*, (*Lectures*, p. 468,) has offered some curious facts connected with this subject, to which I refer the physiological reader. He is of opinion that, in the large intestines, a portion of the food unfit for chylification is, by a process not widely different from that above described, converted into fat, which is afterwards absorbed and conveyed to different parts of the body.

In chyle we cannot fail to observe an approximation to blood; it is deficient in colouring-matter, and the albumen which it contains differs somewhat from that existing in the blood itself; it appears, therefore, that the albumen is perfected, and fibrin and colouring-matter formed, in the process of circulation.

The difference between arterial and venous blood has been adverted to in a previous section; the former is of a florid-red colour, and circulates in the arterial system; it is contained in the left ventricle of the heart, and thence carried by the *aorta*, and its ramifications, to every part of the body, tending to reproduction and secretion: it afterwards enters the veins which arise from the extremities of the arteries, and form accompanying branches, and trunks, ultimately uniting in the *venæ cavæ*, which pour their contents into the right auricle of the heart; the venous blood is thence propelled into the right ventricle, from which the pulmonary artery arises, transmitting it through the lungs, whence it is returned by the pulmonary vein into the left auricle, which transmits it to the left ventricle, from which issues the aorta as aforesaid. So that the right cavities of the heart receive venous blood, and transmit it through the lungs, whence it returns to the left side of the heart, in the arterial state. In the lungs the blood is infinitely subdivided, and spread over a very large surface, in vessels so delicate as to admit of the operation of the atmospheric air contained in their cells; it enters the pulmonary structure in the *venous* state by the *pulmonary artery*, and returns in the *arterial* or *aërated* state, by the *pulmonary vein*. It now remains to examine the changes which the blood undergoes during pulmonary circulation.

Respiration is the process of receiving a quantity of air into the lungs, whence, after having been retained a short time, it is again expelled in the action of expiration: and, if now examined, a portion of its oxygen is found exchanged for carbonic acid, and it is more or less loaded with aqueous vapour. The nitrogen of the air probably remains passive, although from Dr. Edwards's experiments there appears to be some doubt upon this subject, for sometimes it appeared to be emitted, and sometimes absorbed in small quantities by the blood. (*De l'Influence des Agens Physiques sur la Vie*, 1824.)

Obvious circumstances render it very difficult to ascertain the quantity of air taken into the lungs at each natural inspiration, as well as the number of respirations made in a given time; the former is, perhaps, about 15 or 16 cubic inches; and the latter about 20 in a minute.

It has been by some supposed that the air suffers an absolute diminution of bulk, but the experiments that have been adduced to prove this, can, I think, scarcely be regarded as satisfactory; it seems, on the contrary, most probable that the *volume* of air expired is exactly equal to that inspired, and consequently the only chemical change that is evident is the saturation of a portion of its oxygen with carbon*. The quantity of carbonic acid emitted at each expiration, varies at different periods of the day, and probably also in different individuals; it appears at its maximum during digestion, and at its minimum in the morning, when the stomach is empty, and when no chyle is flowing into the blood. Dr. Prout has shown that fermented liquors and vegetable diet diminish the proportion of carbonic acid, and that the same thing happens when the system is affected by mercury. (Thomson's *System*, iv., 621.)

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* Dr. Edwards thinks that a portion of air disappears, but that it is very variable in its amount. (Bostock, *Physiology*, ii., 101.)

The air expired after a single expiration has generally been regarded as containing, on an average, 3.5 *per cent.* of carbonic acid; Messrs. Allen and Pepys, however, in their *Essay on Respiration* (*Phil. Trans.*, 1808,) have estimated it at about twice that quantity; it amounted, in their experiments, to between 26 and 27 cubic inches per minute, a considerable quantity, when we reflect upon the comparative proportion of carbon existing in our food, and the other means of escape which it has from the body.

The following table shows the results of several experimentalists in reference to the average quantity of air required for respiration, and of carbonic acid produced, by a man. (Gmelin.)

	Of oxygen required in 24 hours.		Carbonic acid produced in 24 hours.		Weight of evolved Carbon.
	Cub. inches.	Grains.	Cub. inches.	Grains.	Grains.
Lavoisier and Seguin	46037	15661	14930	8584	2820 (French.)
Menzies	51480	17625			
Davy	45504	15751	31680	17811	4853
Allen and Pepys	39600	13464	39600	18612	5148

The aqueous vapour contained in the expired air is probably secreted by the exhalants distributed over the surface of the air-vessels of the lungs, and derived from the humidity of the mouth, fauces, and trachea. Attempts have been made to estimate its quantity, but without success; perhaps the nearest estimate is about 3 grains per minute; it is liable to variation, and can scarcely be considered as a product of respiration. It is estimated by Menzies to amount to 2880 grains in the 24 hours; by Abernethy, to 4320; by Thomson, to 9120; by Hales, to 9792; and by Lavoisier to 13,704 grains.

It has been above stated that the whole of the venous blood is propelled through the vessels of the lungs, where it is subjected to the action of the air; the chyle is of course carried along with it, and when it returns by the pulmonary vein to the left side of the heart, it has undergone a considerable change in appearance, having lost its dingy colour, and acquired a fine florid red; the chyle also has become perfect blood. The change of colour is evidently owing to the action of the air, which takes place through the thin coats of the circulating vessels (see p. 1146), and the end thus attained is the removal of the carbonic acid from the venous blood. The only chemical difference, then, which can be satisfactorily detected between arterial and venous blood, is the existence of a certain excess of carbon, or of carbonic acid, in the latter; when this is abstracted, and oxygen substituted for it, the blood is fitted for the renovation of parts, for the formation of secretions, and for the sustenance of life by its action on the cerebral system; for although the heart does not directly refuse to circulate venous blood, torpor ensues when blood, not aërated, passes into the vessels of the brain.

It has already been shown that the blood suffers very important changes in the kidneys and liver; the function of *perspiration* also must be considered as connected with an alteration of the circulating fluid, for moisture, carbonic acid, and minute quantities of acid, and of saline and animal matter, among which are acetic or lactic acid, acetate and muriate of ammonia, and chloride of sodium* are evacuated by the cutaneous vessels. This quantity of humidity is sometimes very considerable, especially during exercise in warm weather, and it probably contributes materially to diminish the temperature of the body; a portion of water, however, is at all times passing off by the skin, as may be seen by putting the hand into a dry and cold glass, which soon becomes dimmed by the condensation of vapour: this is termed *insensible perspiration.*

Different animals require very different quantities of oxygen for the purposes of respiration. Man, and warm-blooded animals, consume the largest quantity; the amphibious tribes not only require less, but can breathe in an atmosphere which will not support the life of the former; and many insects take such small quantity, as sometimes to have been supposed capable of living without air, which is not the case. In the production of carbonic acid, all animals agree; and, consequently, the nature of the deterioration suffered by the air is similar throughout the animal creation.

Fishes breathe the air which is dissolved in water; they therefore soon deprive it of its oxygen, the place of which is supplied by carbonic acid; this is in many instances decomposed by aquatic vegetables, which restore oxygen, and absorb the carbon; hence the advantage of cultivating growing vegetables in artificial fish-ponds. It has been ascertained by Biot, and verified by others, that the air-bladders of fish that live in very deep water, are filled with a mixture of oxygen and nitrogen, in which the former greatly preponderates; but in fish that are taken near the surface, the nitrogen is most abundant. In the *Trygla lyra*, always caught in very deep water, the air-bladder contained 87 *per cent.* of oxygen: in the carp and roach, according to Fourcroy and Priestley, the air-bladder contains little else than nitrogen. (BIOT, *Mémoires d'Arcueil*, i. and ii.)

The production of *animal heat* is perhaps the most recondite of all the functions; the power appears to belong to all animals, though to some in a very inferior degree. The higher orders of animals always maintain a temperature of about 100°; it varies a little in different parts of the body, the extremities and surface being a degree or two colder than the interior vital organs. This temperature is probably very little affected by external circumstances, a hot or cold atmosphere producing no corresponding change in the heat of the circulating blood.

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* According to Anselmino, as quoted by Tiedemann and by Berzelius, the dry residue obtained by evaporating human sweat, contains

Saline matters, chiefly calcareous, and insoluble in water and in alcohol	2.
Substances soluble in water, but insoluble in alcohol, comprising animal matter and sulphuric salts.	21.
Common salt and extractive matter soluble in dilute alcohol	8.
Extractive matter, lactic acid, and lactates, soluble in anhydrous alcohol	29.
	100.

The relative proportion of solid matter to that of the water, in sweat, varies according to Thenard, from 0.5 to 1.25 *per cent.* (*Ann. de Chim.*, LIX., 262.) Some peculiar matters are occasionally thrown off by the skin, giving rise to *coloured* perspiration. I have heard of a case in which a man's linen was thus tinged blue; and Dr. Williams mentions the case of a lady whose perspiration, when profuse, dyed the clothes on some parts of her person, particularly the wrists and neck, of a bright crimson colour, but without any marks of blood; this was supposed by Dr. Prout to be caused by sulphocyanate of iron.

When the chemical changes that take place during respiration had been inquired into, and when it was found that the capacity of carbonic acid for heat was less than than of oxygen, it was supposed that the conversion of oxygen into carbonic acid was the cause of the rise of temperature; and as the heat of the lungs does not exceed that of other parts, it was asserted that the air was absorbed by the blood, and that the production of carbonic acid, and consequent evolution of heat, took place gradually during the circulation. To these opinions many strong objections have from time to time been urged by different physiologists, but their complete subversion followed the researches of Sir B. Brodie (*Phil. Trans.*, 1812), who found that the heart was capable of retaining its functions for some hours, and of carrying on circulation, in a decapitated animal, and consequently independent of the influence of the brain, when respiration was artificially carried on. Under these circumstances it was observed, that although the change of blood from the venous to the arterial state was apparently perfect, heat was not generated, for the animal cooled regularly and gradually down to the atmospheric standard. In more than one instance I examined, at his request, the expired air, and found that it contained as much carbonic acid as was produced by the healthy animal; so that here, circulation went on, there was the change of oxygen into carbonic acid, and the alteration of colour in the blood, and yet heat appeared not to be generated*.

In these cases, a period was also put to the secretory functions; and it has been observed by other physiologists, that if the nerves that supply any of the glands are injured or divided, there is a corresponding change or suspension of their secretion. Electricity has sometimes been supposed to have some connexion with the nervous influence (p. 301), and the fact of some of the secretions being alkaline, while others are acid, (corresponding to negative and positive influence,) has been adduced in favour of the supposition (*Phil. Trans.*, 1809, p. 385;) but experiment has gone little way to sanction such a notion; and although it has been proved that the *nervous influence* contributes to the generation of heat in animals, and that it presides over the phenomena of secretion, as well as of sensation and voluntary motion, neither the actual cause of this influence, nor the mode in which it operates have been ascertained.

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* Upon this subject Dr. Turner (*Elem. of Chemistry*, 5th edition, 983,) makes the following remarks: Were these experiments rigidly exact they would lead to the opinion that no caloric is evolved by the mere process of arterialisation; this inference however cannot be admitted for two reasons; first, because other physiologists in repeating the experiments of Brodie, have found that the process of cooling is retarded by artificial respiration; and secondly, because it is difficult to conceive why the formation of carbonic acid, which uniformly gives rise to increase of temperature in other cases, should not be attended, within the animal body with a similar effect. It may, hence, be inferred, that this is one of the sources of animal heat. It is certain, however, that the heat of animals cannot be maintained by the sole process of arterialization. Consistently with this fact, the researches of Dulong and Despretz agree in proving, in opposition to the results obtained by Lavoisier and Crawford, that a healthy animal imparts to surrounding bodies a quantity of heat considerably greater than can be accounted for by the combustion of the carbon thrown off during the same interval from the lungs in the form of carbonic acid. (*Ann. de Chim. et Phys.*, xxvi.)

APPENDIX.

I. English Weights and Measures

The English *troy* pound is subdivided into twelve ounces, and each ounce is equal to 480 grains. The subdivisions of the troy ounce, called *Apothecaries' weight*, are into 8 drachms, each drachm into 3 scruples, and each scruple into 20 grains. The troy ounce is also sometimes divided into 20 penny weights, of 24 grains each. These are the weights generally employed by chemists, but for philosophical purposes ambiguity is most easily avoided by employing the grain as integer: and the laboratory should be provided with good sets of weights, from 1000 grains downwards; the grain should be decimally subdivided into tenths and hundredths.

The standard of most articles bought and sold in common life is the *avoirdupois* pound, which is equal to 7000 troy grains, and is divided into 16 ounces, of 437.5 troy grains each. The avoirdupois ounce is legally divided into 16 drachms, of 27.34375 grains each; but this division is rejected in all ordinary cases, in consequence of the confusion likely to result between the troy and avoirdupois drachm, so that the term *drachm* is almost exclusively employed to denote the eighth part of a troy ounce, or 60 grains.

For measures of capacity, the *wine pint* was formerly employed, which corresponds to 28.875 cubical inches of water, at a temperature of 60°. It is subdivided into 16 ounces; the ounce into 8 drachms. Two pints make a quart, and 4 quarts a gallon.

The *ale pint* contains 35.25 cubical inches of water, at 60°.

For chemical use, the most convenient measure is the bulk occupied by the troy ounce of distilled water, which may be subdivided into 480 grains, and which is equal to 1.8047 cubical inches.

The length of the pendulum, vibrating seconds *in vacuo*, in the latitude of London (51° 31′ 8″.4 North) at the level of the sea, and at the temperature of 62°, is = 39.13929 inches of Sir George Shuckburgh's standard scale. (Kater, *Phil. Trans.*, 1819, p. 415.)

In the following Tables are shown the subdivisions of the English troy and avoirdupois pounds, and of the English wine gallon, and their correspondence with the French *gramme* and *litre*.

TROY WEIGHT.

Pound.	Ounces.	Drms.	Scruples.	Grains.	Grammes.
1	12	96	288	5760	372.96
	1	8	24	480	31.08
		1	3	60	3.885
			1	20	1.295
				1	0.06475

AVOIRDUPOIS WEIGHT.

Pound.	Ounces.	Drms.	Grains.	Grammes.
1	16	256	7000	453.25
	1	16	437.5	28.328
		1	27.34375	1.7705

WINE MEASURE.

Gal.	Pints.	Ounces.	Drms.	Cub. Inch.	Litres.
1	8	128	1024	231.	3.78515
	1	16	128	28.875	0.47398
		1	8	1.8047	0.02957
			1	0.2256	0.00396

The IMPERIAL GALLON, *now substituted for all other measures, is one-fifth more than the old wine gallon* (30 *Imperial* = 36 *Wine*), *and one-sixtieth less than the old ale gallon* (31.5 *Imperial* = 30 *Ale.*) *It contains* 10 *pounds of water, of* 7000 *grains each* (*avoirdupois pounds*) = 70,000 *grains* = 277.273 *cubic inches of water at* 62°.

II. FRENCH WEIGHTS AND MEASURES.

THE French metrical system is founded on a single standard of length, called a *metre*, and which is equivalent to the ten-millionth part of the arc of the meridian, extending from the equator to the pole. The length of the metre, at the temperature of 32°, as ascertained by Captain Kater (*Phil. Trans.*, 1818), is 39.37079 English inches.

The French measures increase and decrease in decimal proportions, a distinctive prefix being put to the term by which the integer is called. These prefixes are *deca*, *hecto*, *kilo*, and *myria*, taken from the Greek numerals, to express the *multiplication* of the integer by 10, 100, 1000, and 10000 respectively: and *deci*, *centi*, and *milli*, from the Latin numerals, to express the *division* of the integer by 10, 100, or 1000; as in the following table:

	Metres.		Metre.
1 Myriametre . . .	10000	1 Metre	1
1 Kilometre . . .	1000	1 Decimetre . . .	0.1
1 Hectometre . . .	100	1 Centimetre . . .	0.01
1 Decametre . . .	10	1 Millimetre . . .	0.001

The metre is the integer of the measure of length, and from it all measures of surface, capacity, and weight, are deduced as follows:

For square dimensions, the metre, or its parts squared, are employed. When used for measuring land, the term *are* is adopted, which is a decametre squared. An *hectare*, or 100 *ares*, is about equal to 2 English acres.

For the integer of the measure of capacity, the cubed decimetre is employed, under the name of *litre*, which is about equal to 2⅛ English wine pints.

For the integer of the measure of weight, the weight of a cubic centimetre of distilled water, at 32°, has been adopted: it is called a *gramme*, and is equal to 15.4 English grains.

The following are the principal tables of French Weights and Measures, which will be found useful in the laboratory. In *Appendix* II. of Aikin's *Dictionary*, the reader will find several others, showing the relation of the French to the English standards.

Measures of Length.

		English inches.		Mil.	Fur.	Yds.	Feet.	In.
Millimetre . .	=	.03937						
Centimetre . .	=	.39371						
Decimetre . .	=	3.93710						
Metre	=	39.37100						
Decametre . .	=	393.71000	=	0	0	10	2	9.7
Hecatometre . .	=	3937.10000	=	0	0	109	1	1
Kilometre . . .	=	39371.00000	=	0	4	213	1	10.2
Myriometre . .	=	393710.00000	=	6	1	156	0	6

Measures of Capacity.

		Cubic inches.		*English.*			
				Tons.	Hogs.	Wine G.	Pints.
Millilitre . . .	=	.06103					
Centilitre . . .	=	.61028					
Decilitre . . .	=	6.10280					
Litre	=	61.02800	=	0	0	0.	2.1133
Decalitre . . .	=	610.28000	=	0	0	2.	5.1352
Hecatolitre . .	=	6102.80000	=	0	0	26.419	
Kilolitre . . .	=	61028.00000	=	1	0	12.19	
Myriolitre . .	=	610280.00000	=	10	1	58.9	

Measures of Weight.

		English grains		*Avoirdupois.*		
				Poun.	Oun.	Dram.
Milligramme . .	=	.0154				
Centigramme . .	=	.1544				
Decigramme . .	=	1.5444				
Gramme . . .	=	15.4440				
Decagramme . .	=	154.4402	=	0	0	5.65
Hecatogramme .	=	1544.4023	=	0	3	8.5
Kilogramme . .	=	15444.0234	=	2	3	5
Myriogramme .	=	154440.2344	=	22	1	2

III. Table of the Specific Gravity of Water, at every degree of Temperature, from 30° to 80° Fahr.

The following Table is given by Mr. Gilpin, in the 84th volume of the *Philosophical Transactions*, and is of essential use for taking the specific gravities both of solids and fluids, by enabling the operator to reduce the weight or bulk of the distilled water employed in any case, to that which it would have at any other common temperature, and particularly to 60°, which is the usual standard.

Thus, for example, since the specific gravity of water at 47° is 1.0008, and at 60° is 1.00000, (and consequently 1.0008 grains, at 47°, are equal in bulk to 10,000 grains at 60°), it follows that it would require 252,708 grains, at 47°, to equal the space of a cubic inch: for 10,000 : 10,008 : : 252,506 (the weight of a cubic inch at 60°), : 252,708.

The remarkable anomaly of the specific gravity of water *decreasing* through all the degrees of temperature below 40°, or thereabouts, that it remains uncongealed, has been noticed under the article HEAT; but the difference for one or two degrees above or below 40° is so trifling, that it has hardly yet been ascertained with perfect accuracy.

Fahr.	Sp. Grav.	Fahr.	Sp. Grav.	Fahr.	Sp. Grav.	Fahr.	Sp. Grav.
30° ...	1.00074	43° ...	1.00090	56° ...	1.00031	69° ...	0.99906
31 ...	1.00078	44 ...	1.00088	57 ...	1.00024	70 ...	0.99894
32 ...	1.00082	45 ...	1.00086	58 ...	1.00016	71 ...	0.99882
33 ...	1.00085	46 ...	1.00083	59 ...	1.00008	72 ...	0.99869
34 ...	1.00088	47 ...	1.00080	60 ...	1.00000	73 ...	0.99856
35 ...	1.00090	48 ...	1.00076	61 ...	0.99991	74 ...	0.99843
36 ...	1.00092	49 ...	1.00072	62 ...	0.99981	75 ...	0.99830
37 ...	1.00093	50 ...	1.00068	63 ...	0.99971	76 ...	0.99816
38 ...	1.00094	51 ...	1.00063	64 ...	0.99961	77 ...	0.99802
39 ...	1.00094	52 ...	1.00057	65 ...	0.99950	78 ...	0.99788
40 ...	1.00094	53 ...	1.00051	66 ...	0.99939	79 ...	0.99774
41 ...	1.00093	54 ...	1.00045	67 ...	0.99928	80 ...	0.99759
42 ...	1.00092	55 ...	1.00038	68 ...	0.99917		

IV. ANALYSIS OF MINERAL WATERS.

THE following observations may perhaps be useful in directing the student's attention to a few of the leading points in the examination of mineral waters. The means of calculating the composition of the precipitates, and other details of quantitative analysis, are not here repeated, as they are fully explained in other parts of this work. The principal tests and re-agents which he will require are as follows:

Pure sulphuric acid.
,, nitric acid.
,, muriatic acid.
Dilute sulphuric acid, 1 acid + 3 water.
,, nitric acid ,, ,,
,, muriatic acid ,, ,,
Solution of potassa.
,, soda.
,, ammonia.
,, carbonate of potassa.
,, carbonate of soda.
,, carbonate of ammonia.
,, oxalic acid.
,, oxalate of ammonia.
,, baryta.
,, acetate of baryta.
,, lead.
Solution of nitrate of baryta.
,, phosphate of soda.
,, sulphate of silver.
,, iodine in alcohol.
,, nitrate of silver.
,, ferrocyanuret of potassium.
,, chloride of calcium.
,, hydrosulphuret of ammonia.
,, iodide of potassium.
,, soap in alcohol.
,, chloride of platinum.
Tincture of galls.
Phosphorus.
Sulphate of lime.
Test-papers, (turmeric, litmus, violet.)
Black flux.
Nitrate of ammonia.

The following will also be requisite: Florence flasks, Wedgwood and glass basins, a platinum and a silver crucible, a silver capsule, some funnels, test-glasses, test-tubes, and glass rods, filtering-paper, a spirit and an Argand lamp, a retort and receiver, a copper basin to serve as sand-bath, a blowpipe, a thermometer, a scale of equivalents, a dropping-bottle, a few watch-glasses, a support for holding glasses over a lamp, a small brass stand with rings, a pipette for drawing up small portions of liquids, platinum pincers; a small but good balance, with well-adjusted weights, is also requisite, accompanied by a phial and counterpoise for taking specific gravities; and, lastly, a small mercurial trough. There should also be a plentiful supply of distilled water, a portion of which should be contained in a dropping-bottle. These tests and apparatus, with instructions for their use, may be obtained at Mr. Newman's, Regent-street.

I. i. The term *Mineral Water*, is applied to those natural spring-waters which contain so large a proportion of foreign matter as to render them unfit for common domestic use, and to confer upon them a sensible flavour, and a specific action upon the animal frame. Their temperature is liable to variation, and is sometimes their principal character, as is the case with the waters of Bath and Buxton; but they are generally so far impregnated with acid or saline bodies, as to derive from them their peculiarities, and in this respect may conveniently be arranged under the heads of *carbonated*, *sulphureous*, *saline*, and *chalybeate* waters. (See the annexed table.) The mere taste of the water enables us to determine to which of these subdivisions it probably belongs.

ii. In examining a mineral water, it is of importance to ascertain its *specific gravity*, which gives some insight into the proportion of its saline ingredients. Mr. Kirwan (*Essay on Mineral Waters*, p. 145) has given the following formula for calculating the proportion of saline substances in a water of known specific gravity: "subtract the specific gravity of pure water from that of the water examined, and multiply the remainder by 1.4. The product is equal to the saline contents in a quantity of the water denoted by the number employed to indicate the specific gravity of distilled water. Thus, suppose the specific gravity of the water $= 1.079$, and that of pure water $= 1.000$, then $79 \times 1.4 = 110.6 =$ saline contents in 1000 of the mineral water." It is advisable to conjoin this method with the following:

iii. Evaporate a given weight, say 1000 parts, to dryness, and expose the residue for 24 hours to a temperature not exceeding 300° upon a platinum capsule; weigh it while warm, and the mean obtained from this and the former experiment will give the proportion of dry saline ingredients within a trifling error. Thus, suppose 1000 parts of the above-mentioned water give by evaporation 114.4 dry residue, then $110.6 + 114.4 = 225 \div 2 = 112.5 =$ quantity of saline matter in a dry state (salts deprived of water of crystallization) existing in the water.

iv. Having ascertained the relative *quantity* of foreign matter in the water, the *nature* of the substances present is next to be inquired into. The substances which have been found in mineral waters are extremely numerous, as may be seen in the annexed analyses by Berzelius and Struve: those which very ordinarily occur are the following:—Oxygen, nitrogen, carbonic acid, sulphuretted hydrogen, carbonate of lime, carbonate of magnesia, carbonate of iron, muriate of magnesia, chloride of sodium, sulphate of magnesia, sulphate of soda, and sulphate of lime.

a. Oxygen and nitrogen exist in the greater number of spring-waters in the proportions constituting atmospheric air; the proportion of nitrogen is, however, not unfrequently predominant. These gases give no peculiar flavour to the water.

b. Carbonic acid renders waters sparkling and effervescent: it is detected by occasioning a precipitate in aqueous solution of baryta, which dissolves with effervescence in dilute muriatic acid.

c. The presence of sulphuretted hydrogen is known by its odour; by the production of a black precipitate, on dropping into the water a solution of nitrate of silver; and by the deposition of sulphur, on adding a few drops of nitric acid.

d. The carbonates are dissolved in the water by excess of carbonic acid, and consequently fall upon its expulsion by boiling. Carbonate of lime and magnesia are deposited in the form of a white precipitate. Carbonate of iron occasions the separation of a brown powder, and the water is blackened by a few drops of tincture of galls.

e. Mr. Phillips, in his analysis of Bath waters, has shown that the delicacy of galls, as a test for iron, is affected by the presence of certain salts: if the iron be in the state of protoxide, its detection is facilitated by salts with a base of lime, and by alkalis; if in the state of peroxide, lime prevents the action of the test. This is well shown by dissolving a *very* minute portion of protosulphate of iron in a glass of distilled water, and adding a drop of tincture of galls, which occasions no immediate discoloration; but a drop of lime-water, or other alkali, instantly renders the presence of iron evident; so that the quantity of iron present in a water cannot be correctly judged of by the degree of precipitation occasioned in it by tincture of galls.

f. Ferrocyanuret of potassium is also a good test to show minute quantities of iron in water, by the blue precipitate which it occasions; its action is aided by previously adding two or three drops of nitric acid to the water; but it is an equivocal test compared with galls.

g. The presence of chlorides or muriatic salts is indicated by a white cloud, insoluble in nitric acid, on adding sulphate of silver.

h. The sulphates, when present in water, afford a white precipitate on the addition of nitrate of baryta, which is insoluble in nitric acid.

i. Lime is recognised by a white cloud on dropping oxalate of ammonia into the water. A portion of the precipitate collected upon leaf-platinum, and heated before the blow-pipe, may be burned into quicklime.

k. Magnesia is rendered evident by adding carbonate of ammonia, which throws down the lime, and subsequently dropping in phosphate of soda, which, when magnesia is present, carries it down in the form of a granular precipitate of ammoniaco-magnesian phosphate.

Such are the readiest means of recognising the presence of the various substances that *commonly* occur, by the action of re-agents or tests; and, having gained such general information, we next proceed to the analysis of the water, in order to ascertain the relative proportions of the gaseous and saline ingredients which it holds dissolved.

II. v. To ascertain the relative proportions of the gaseous contents of water with perfect accuracy, is difficult, and rarely necessary; the following method is sufficiently precise in all ordinary cases. Provide a Florence flask capable of holding rather more than a measured wine-pint, which quantity of the water under examination is to be introduced into it, and a cork carefully fitted to its neck, through a perforation, in which is inserted a glass tube one-eighth of an inch in diameter, rising perpendicularly about eighteen inches, and then bent so as to pass conveniently under the shelf of the mercurio-pneumatic apparatus. (Where a sufficiency of mercury cannot be procured, warm water may be substituted, if only carbonic acid be present, and it may be absorbed by transferring the jar containing it to a solution of potassa.) The flask should be placed over an Argand lamp, and heat gradually applied till the water fully boils. The gas evolved is to be collected in the usual way, in a graduated jar over quicksilver, and submitted to the following examination:—

vi. Throw up a small quantity of solution of potassa, which, if *carbonic acid* be present, will absorb it, and the quantity will be shown by the diminution of bulk.

vii. Introduce the remaining air, or a portion of it, into a small bent tube, containing a bit of phosphorus; heat it so as to kindle the phosphorus, and note the diminution of bulk when cold. It is proportional to the *oxygen* present, and, if equal to one-fifth of the whole bulk, the gas may be regarded as *atmospheric air*.

viii. If *sulphuretted hydrogen* be present it may be separated by alcoholic solution of iodine, which absorbs it, and scarcely takes up more than its own volume of carbonic acid gas. Chlorine, added to a mixture of sulphuretted hydrogen and carbonic acid, will also produce the absorption of the former, if a little water be present; but it cannot be conveniently used over mercury.

ix. During the ebullition it not unfrequently happens that a precipitation ensues, indicating that the substances thrown down were dissolved by carbonic acid; and in that case they should be separated upon a filter, A; after which the remaining water may be evaporated to dryness in a glazed porcelain basin; the dry residue must be transferred to a silver capsule, and perfectly desiccated at a temperature not exceeding 500°. B.

The precipitate A may consist of carbonate of lime, of carbonate of magnesia, or of oxide of iron; or it may be a mixture of the three; dissolve it in dilute muriatic acid, and add oxalic acid, which throws down oxalate of lime; separate this by filtration, and saturate the filtrated portion with carbonate of ammonia, which precipitates the peroxide of iron, and having removed this, evaporate the residuary mixture, and expose the dry salt to a red heat in a small platinum capsule; the *magnesia*, if any were present, will remain; if not, there will be no residue; for the oxalic acid and muriate of ammonia will be destroyed and volatilized.

When carbonic acid holds iron in solution, the metal is in the state of protoxide, and if air be excluded, it requires long boiling to decompose it; for the same reason, if the water be exposed under the exhausted receiver of the air-pump, it does not readily become brown, as is the case when it is exposed to air; a drop or two of nitric acid facilitates the deposition of the red oxide.

x. The dry residue B, is to be digested in six or eight parts of boiling anhydrous alcohol, which will take up *muriate of magnesia*, and in some rare cases (where no sulphates are present) *muriate of lime*. Filter off the alcoholic solution, and wash the residue C with a little fresh alcohol, which add to the former, and evaporate to dryness D. The dry mass D, exposed for some time to a heat of 500°, is generally pure *muriate of magnesia:* if it contain *muriate of lime*, the latter earth may be separated by solution of oxalic acid, in the state of oxalate of lime.

It is, in some cases, convenient to convert the muriates of lime and magnesia into sulphates, by pouring upon them excess of sulphuric acid, evaporating to dryness, and heating the dry mass red hot. The sulphate of magnesia may then be almost completely separated from the sulphate of lime, by a small quantity of cold water; or a saturated solution of sulphate of lime may be used, which takes up the sulphate of magnesia, and leaves the sulphate of lime.

xi. The residue C, insoluble in alcohol, may contain *chloride of sodium*, *sulphate of soda*, *sulphate of magnesia*, and *sulphate of lime;* digest it in ten parts of boiling distilled water, which, when cold, will have taken up everything but *sulphate of lime*, of which an inappreciable portion only will have been dissolved; separate the solution into two equal portions, *a* and *b*, which may afterwards be further diluted.

To *a* add nitrate of silver, and wash and dry the precipitate, which is chloride of silver, 146 parts indicate 60 of chloride of sodium.

To *b* add acetate of baryta as long as it occasions a precipitate, which is sulphate of baryta, E, and which is to be separated, dried, and weighed. 117 grains are equivalent to 72 of dry sulphate of soda and 60 of dry sulphate of magnesia.

In order to ascertain the quantity of *magnesia* present, and consequently the quantity of *sulphuric acid* belonging to it, evaporate the liquid filtered off the barytic precipitate E to dryness; it will contain chloride of sodium, acetate of soda, acetate of magnesia, and, probably, a portion of the added acetate of baryta; ignite the dry mass, and wash it to separate the chloride of sodium and the soda; magnesia and carbonate of baryta will remain insoluble, upon which pour dilute sulphuric acid; digest, filter, and evaporate the clear liquor to dryness; it is sulphate of magnesia, equivalent of course to the original portion of the salt; deduct the sulphuric acid contained in it from the whole in the precipitate E, and the remainder will give the quantity united to the soda.

xii. To estimate the quantity of *sulphate of lime* in the water, the residue of the evaporation of one pint may be washed with cold saturated solution of sulphate of lime, which, in most cases, will dissolve everything but that sulphate, and which may thus be obtained and weighed; or, add oxalate of ammonia to a given quantity of the boiled and filtered water, collect the precipitate, and give it a red-heat with excess of sulphuric acid, by which it is converted into *sulphate of lime*, equivalent to the original in the water.

xiii. Besides the substances now enumerated, and which may be considered as the most frequently occurring ingredients in mineral waters, the following are occasionally present:

a. Carbonate of Soda is known to exist in water, when, after having been boiled down to half its bulk, and, if necessary, filtered, it reddens turmeric paper, and restores the blue of litmus reddened by vinegar; it also affords an effervescent precipitate with nitrate of baryta, soluble in dilute nitric acid. This carbonate is incompatible with the soluble salts of lime.

Muriate of lime may also be used to detect the alkaline carbonates, with which it affords a precipitate of carbonate of lime. Carbonate of soda is distinguished from that of potassa, by the latter affording a precipitate in neutral muriate of platinum, which the former does not. *Carbonate of ammonia* is discoverable by its smell, when acted on by caustic fixed alkali or lime: also by its action on test-papers.

b. *Silica* is detected by evaporating the water to dryness, and boiling the residue in dilute muriatic acid. The silica, if present, remains as a white powder not altered by a red-heat, but instantly fusing with a particle of carbonate of soda.

Boracic acid and *borax* have been found in certain lakes in India, and in some parts of Italy. To detect boracic acid, evaporate to one-eighth the original bulk of the water, and add carbonate of soda as long as it occasions any precipitate; boil and filter. The filtered liquor will contain borate of soda with some other salts of the same basis; evaporate to dryness in a platinum crucible, and digest the residue in three or four parts of sulphuric acid, diluted with its bulk of water. If boracic acid be present, it will separate in micaceous crystals.

d. *Alumina* has been found in a few mineral waters in the state of a *sulphate.* It may be separated by the following process: Evaporate to dryness, digest in alcohol, and redissolve the residue in eight parts of water; filter and add oxalic acid, which throws down lime, and which, being separated, leaves magnesia and alumina in solution. Carbonate of ammonia throws down the alumina and leaves the magnesia.

Pure ammonia throws down both alumina and magnesia. These earths may be separated by solution of potassa, which dissolves the former but not the latter.

e. *Manganese* is sometimes found in water, but only in very small proportion, so as not to amount to more than a trace. Dr. Scudamore found a trace of manganese in the waters of Tunbridge Wells, and it has never been discovered in larger proportion.

f. Certain *nitrates* are occasionally present in water. Nitrate of lime will be taken up from the residue of evaporation by alcohol, and may be decomposed by carbonate of potassa, so as to afford carbonate of lime and crystals of nitre.

g. It sometimes happens that water contains *lead*, which may be detected by evaporation to one-eighth its bulk, adding a few drops of nitric acid, and then sulphate of soda, which gives a white insoluble precipitate; and sulphuretted hydrogen, which forms a black cloud. These precipitates may be reduced by heating them before the blowpipe upon charcoal, mixed with a little black flux.

h. If *vegetable or animal matter* be contained in water, it gives it a brown colour, especially when evaporated. It may be destroyed in the dry residue by igniting it with a small addition of nitrate of ammonia.

i. *Iodine* and *Bromine* must always be sought for in mineral waters; the means of detecting these are stated at pp. 341 and 344. Where they are suspected, the water should be evaporated to dryness, and the residue triturated with a little distilled water, which will take up the iodic and bromic salts; they are recognised by the addition of a solution of starch, having previously added a few drops of solution of chlorine. Or the methods of electrolytic analysis pointed out at p. 280 may be adopted, using a few drops of the evaporated water and of the tests, in a watch-glass.

The following analyses of mineral waters may be consulted by the student, as containing a variety of useful details, necessarily omitted in the above observations:—*Analysis of the Hot Springs at Bath*, by Richard Phillips, Esq. *Analysis of the Brighton Chalybeate*, by Dr. Marcet. *Analysis of the Tunbridge Wells Waters*, by Dr. Scudamore. Mr. Children's *Translation of* Thenard's *Essay on Chemical Analysis*, chapter vi. Walcker *on the Bath Waters*. (*Quart. Journ., N. S.*)

The annexed Tables show the composition of some of the principal mineral waters of Europe. In regard to those of Germany, the older analyses of Bergman, Klaproth, and Hassenfratz, may be compared with the later results of Berzelius and Struve. Traces of iodine and of bromine have also been detected in several mineral waters, in which they had previously escaped observation.

Traces of *organic matter* (zoogen) have been found in certain mineral springs, especially in those of high temperatures, possessing some of the characters of albumen: it was first, I believe, observed by Vauquelin, in the waters of Vichy, (*Ann. de Chim. et Phys.*, xxviii. 98,) and afterwards by Monheim, in those of Aachen, Spa, Heilstein, Malmedy, &c.; the waters of Aix, in Savoy, and of Ischia, acquire a peculiar odour, resembling that of boiled meat, from the presence of this organic matter, and the latter deposit it, according to Gimbernat, upon the adjacent rock. The source of this contamination is a curious subject of geological speculation. The spring-water of London, is not unfrequently contaminated by various impurities of organic origin, sometimes in very sensible quantity; at others, only recognised on evaporating it, when the residue exhales a peculiar odour, and evolves ammonia if heated or acted on by caustic alkali. The source of this contamination, especially in the pump-water from church-yards, is sufficiently obvious; and such is the situation generally chosen for the parish pump. This disgusting source of water should be avoided, and the disgraceful system of burying bodies in the streets of London should be authoritatively discontinued*.

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* Abundant instances of this nuisance must occur to every one who walks about London: the church-yard of St. Clement's, in the Strand, is a fair specimen: there are many infinitely worse.

TABULAR VIEW OF THE COMPOSITION OF MINERAL WATERS.

One Pint (Wine Measure) contains the following Ingredients:

WATERS.	GASES.			CARBONATES.			SULPHATES.			MURIATES.			Oxide of Iron.	Silica.	Temperature.	Total of Saline Contents.	AUTHORITY.
	Nitrogen C. I.	Carbonic Acid, C. I.	Sulphuretted Hydrogen, C. I.	Carbonate of Soda, grains.	Carbonate of Magnesia, grains.	Carbonate of Lime, grains.	Sulphate of Soda, grains.	Sulphate of Magnesia, grains.	Sulphate of Lime. grains.	Muriate of Soda, grains.	Muriate of Magnesia, grains.	Muriate of Lime.					
CARBONATED.																	
Seltzer	...	17.	...	4.	5.	3.	...	...	...	17.	...	...	...	...	Cold	29.	Bergman.
Pyrmont	...	26.	...	...	10.	4.5	...	5.5	8.5	1.5	...	...	0.6	...	do.	30.6	Ditto.
Spa	...	13.	...	1.5	4.5	1.5	...	...	...	0.2	...	...	0.6	...	do.	8.3	Ditto.
Carlsbad	...	5.	...	5.	...	1.5	8.5	...	...	4.5	...	...	a trace	0.3	165°	19.8	Klaproth.
Pouges	...	30.	...	10.	1.2	12.	...	...	...	2.2	...	...	2.5	0.5	Cold	28.4	Hassenfratz.
Saint Parize	...	22.	...	...	0.5	11.5	...	...	13.	...	...	...	...	...	do.	25.	Ditto.
SULPHUROUS.																	
Harrogate	0.8	1.	2.3	...	0.7	2.5	...	1.3	...	77.	11.	1.5	...	...	do.	94.	Garnet.
Moffat	0.5	0.6	1.2	...	...	...	...	...	...	4.5	...	...	...	...	do.	4.5	Ditto.
Aix-la-Chapelle	...	...	5.5	12.	...	4.2	...	...	...	5.	...	...	...	...	143°	21.2	Bergman.
Cheltenham Sulphur Spring	...	...	1.5	...	...	...	23.5	5.	1.2	35.	...	...	0.3	...	Cold	65.	Parkes & Brande
SALINE.																	
Seidlitz	...	...	...	...	2.5	0.8	...	180.	5.	...	4.5	...	...	...	do.	192.8	Bergman.
Cheltenham pure Saline	...	...	...	...	...	...	15.	11.	4.5	50.	...	...	...	...	do.	80.5	Parkes & Brande
Bristol	...	3.5	...	...	...	1.5	1.5	...	1.5	0.5	1.	...	...	...	74°	6.	Carrick.
Buxton	0.2	...	...	...	...	1.3	...	...	0.3	0.2	...	...	0.03	...	82°	1.83	Pearson.
Bath	...	1.2	...	...	...	0.8	1.5	...	9.	3.3	...	...	a trace	0.2	116°	14.6	Phillips.
Scarborough	...	...	...	...	...	a trace	20.	...	9.	...	...	...	ditto	...	Cold	2.9	Saunders.
Barège	...	...	uncertain	2.5	...	ditto	...	...	a trace	0.5	...	...	...	...	120°	3.	Ditto.
Plombières	...	...	...	2.2	...	0.3	2.3	...	...	1.5	...	...	...	0.3	?	66.	Vauquelin.
Kilburn	...	3.5	8.5 ?	...	0.5	1.	12.	37.	5.5	2.5	5.5	0.2	a trace	...	Cold	64.2	Schmeisser.
Leamington New Bath	0.4	a trace	a trace	...	...	...	19.	...	14.	53.	1.5	...	0.8	...	do.	88.3	Lambe.
Leamington Old Bath	0.3	...	ditto	...	...	...	7.5	7.	18.	41.	...	...	...	...	do.	73.5	Ditto.
CHALYBEATE.																	
Tunbridge	0.59	1.	{a trace of oxygen}	...	...	0.03	...	...	0.17	0.30	0.03	0.05	0.28	...	do.	0.56	Scudamore.
Cheltenham Chalybeate	...	2.5	...	0.5	...	...	22.7	6.	2.5	41.3	...	...	0.8	...	do.	73.8	Parkes & Brande
Brighton	...	2.2	...	...	...	...	...	...	4.	3.	0.75	...	1.4	0.14	do.	9.29	Marcet.

TABLE OF ANALYSES OF THE PRINCIPAL MINERAL WATERS OF GERMANY.

Ingredients found in 16 oz. of Water in a dry state, in Grains.	Carlsbad.	Ems.	Marienbad. Kreutzbr.	Auschowitz. Ferdinands-brunnen.	Eger. Franzensbr.	Pyrmont.	Spa.	Geilnau.	Selters.	Seidschutz.	Pullna.
Carbonate of Soda . . .	9.695	10.750	8.26	6.197	5.00	...	0.7375	6.6210	6.155	...	...
Sulphate of Soda . . .	19.689	...	39.72	22.544	25.50	2.14566	0.0375	0.0420	...	23.4960	123.8
Muriate of Soda . . .	7.975	7.634	12.45	8.996	7.96	...	0.44949	0.5430	17.292	...	...
Sulphate of Potash . .	...	0.540	0.93	...	0.93	0.04194	0.07909	0.2872	0.397	4.8940	4.8
Muriate of Potash . .	...	0.045	...	...	...	...	...	...	0.358	...	...
Carbonate of Lime . .	2.37	1.1407	4.1300	4.016	1.847	5.98824	0.9850	2.9705	2.1870	6.8060	0.77
Sulphate of Lime . . .	...	...	...	...	...	7.22132	...	...	...	1.5050	2.6
Sub-phosphate of Lime .	0.0017	...	...	...	0.014	...	0.01366	...	...	0.0156	0.0035
Fluate of Lime . . .	0.024	0.00192	...	...	...	...	...	...	0.0018	...	...
Carbonate of Magnesia .	1.369	0.7887	3.0560	2.4	0.600	0.32352	1.12278	2.1709	1.3780	1.0980	6.406
Sulphate of Magnesia .	...	...	...	...	...	2.69752	...	...	...	83.1380	93.086
Muriate of Magnesia . .	...	...	...	...	...	1.12664	...	...	...	1.6300	19.666
Nitrate of Magnesia . .	...	...	...	...	...	...	...	...	...	7.9070	...
Alumina	...	...	0.0075	...	...	...	...	0.0247	...	...	...
Sub-phosphate of Alum	0.0024	0.0018	...	...	...	0.01478	0.00851	...	0.0027	0.0117	...
Carbonate of Strontian .	0.007	0.0107	...	...	...	...	...	...	0.0192	...	...
Sulphate of Strontian . .	...	...	...	...	...	0.02063	...	...	...	0.0463	...
Carbonate of Barytes .	...	0.0029	...	...	...	...	...	...	0.0019	...	...
Silica	0.577	0.4139	0.8800	0.669	0.568	0.49689	0.4985	0.2695	0.302	0.1200	0.176
Carbonate of Iron . .	0.0278	0.026	0.1760	0.4	0·350	0.42846	0.3751	...	...	0.0127	...
Carbonate of Manganese	0.006	0.0037	0.0065	0.092	0.006	0.04852	0.0519	...	...	0.0042	...
Total	41.9239	21.35932	69.616	45.314	42.775	20.55412	4.35903	12.9288	28.0946	130.6845	251.3075
Carbonic Acid Gas in 100 cubic inches . .	58	51	125	149.56	154	160	136	163.3	130	6.4	6.9
Temperature (F) . . .	Sprud. 165° Neub. 138° Mühl. 128° Ther. 122°	Kess. 117° Krän. 84°	53.°	49.°	53.°	56.°	50.°	51.°	58.°	58.°	58.°
Analyzed by	Berzelius.	Struve.	Struve.	Steinmann	Struve.	Struve.	Struve.	Struve.	Struve.	Struve.	Struve.

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